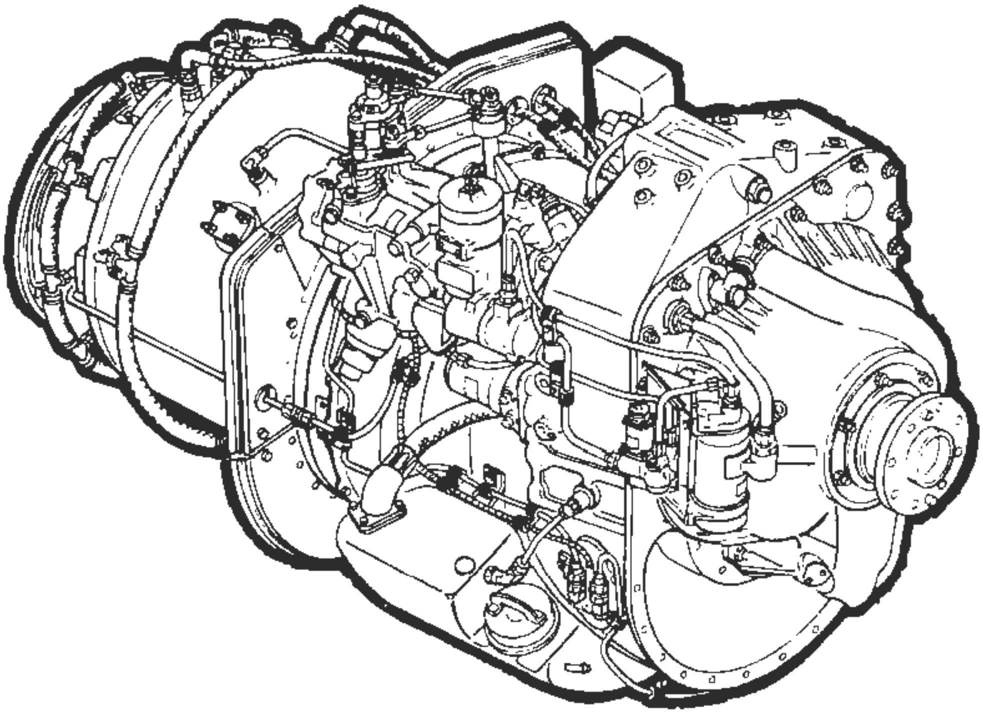
TPE331

TSG-103
REVISED
5-1-81
PROGRAM 7201

TURBOPROP ENGINE

(WOODWARD FUEL CONTROL)



STUDENT GUIDE

PREPARED BY:

TECHNICAL TRAINING CENTER
GARRETT TURBINE ENGINE CO.
PHOENIX, AZ 85010

FOREWORD

Training Study Guides are provided by the Garrett Turbine Engine Company for the limited purpose of presenting familiarization, illustrations and general information to students in support of a specific training course only.

Information contained herein is intended only as a general description of operation to permit intelligent maintenance and systematic troubleshooting of the subject system or components described herein.

It is not the intent of the Garrett Corporation that any training publication be used as a supplement to, or in lieu of, any official publication. Contents herein are subject to change without notice.

The reader of this manual is reminded that all values of pressure, temperature, speed, power, etc. are chosen for their illustrative meaning only and are not necessarily representative of true values. For actual values, the applicable Maintenance Manual must be consulted.

Official publications pertaining to operating procedures; limits and capabilities of engines or their components are the responsibility of the airframe manufacturer. The airframe manufacturer installs the engine in its airframe, designs and/or selects instruments, and flight tests the aircraft. The airframe manufacturer determines how--and under what limitations--engines will be operated for all modes of taxi and flight.

As an engine and engine component manufacturer, the Garrett Turbine Engine Company of Arizona has the responsibility to alert airframe manufacturers that their aircraft manuals not permit operation beyond the limits of an engine's capabilities. Garrett may suggest and advise--but not dictate--operational and maintenance practices it feels best for the engine. Some aircraft manufacturers will assimilate Garrett manuals into their own publications while other manufacturers may simply refer the owner/operator to Garrett published manuals.

Official publications which apply to all engines and systems are listed below (with the highest ranking manual first):

1. Aircraft Flight Manual
2. Aircraft Maintenance Manual
3. Engine Maintenance Manual and Service Bulletins
4. Engine Overhaul Manual and Service Bulletins
5. Component Overhaul Manual and Service Bulletins

It was not accidental that this training manual is not included in the above list of publications:

IT HAS NO OFFICIAL STATUS

IN ALL INSTANCES, INFORMATION CONTAINED IN

OFFICIAL PUBLICATIONS SHALL GOVERN.

GENERAL INSTRUCTIONS

FOR WORKBOOK EXERCISES

This combination training study guide and workbook contains a series of multiple choice exercises which will give you the opportunity to reinforce your understanding of the material covered. These exercises are not intended to be a quiz or a test. Their primary purpose is to serve as a learning experience for you. They will also be used to let you and your instructor know how well you have grasped the various subjects presented.

Your instructor will provide you with a pink Exercise Answer Sheet. Transfer the answers you select during completion of each of the ten workbook exercises to this answer sheet by marking "X" in the appropriate square. This answer sheet will then be graded and returned to you each day. It is the only record of your progress--DO NOT LOSE IT!!!

NOTE: The illustrations in this study guide duplicate the key sequences of the slides used in the lecture program and have corresponding sequence numbers.

TABLE OF CONTENTS

SECTION ONE:

DESCRIPTION AND RATINGS

WHY TURBOPROPS?

ALL TURBINE ENGINES ARE BASICALLY THE SAME EXCEPT FOR THE METHOD USED TO CONVERT HIGH SPEED TURBINE ENERGY INTO USEABLE THRUST TO MOVE THE AIRCRAFT

- TURBOJET — TJE
- TURBOPROP — TPE
- TURBOFAN — TFE

TT-0604-3

#7

All turbine engines are basically the same. The difference between engines lies in their method of converting turbine energy into useable thrust. Three common methods of conversion are: Turbojet, Turboprop and Turbofan. These terms are abbreviated TJE, TPE and TFE. These three abbreviations are used to signify the model designation of these various Garrett engines.

THRUST

ENGINE THRUST IS DEVELOPED IN ACCORDANCE WITH NEWTON'S SECOND LAW...

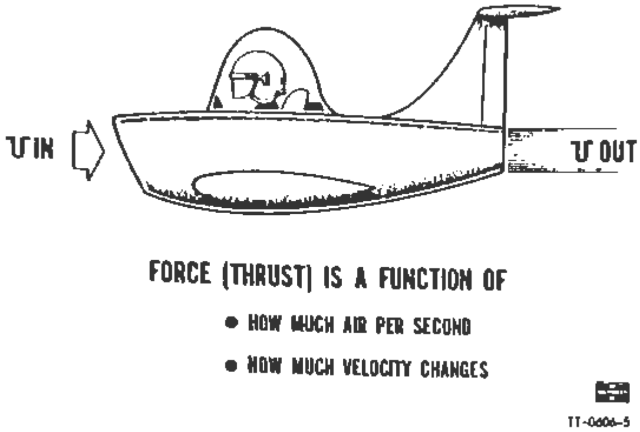
FORCE = MASS × ACCELERATION

TT-0606-4

#8

The concept of engine thrust can be related to the example shown in this illustration. The mass of the bullet times the acceleration equals a force. This equation is known as Newton's Second Law. We do not, however, have to limit mass in this equation to a solid bullet. Air also has mass properties of weight and dimension.

THRUST FUNCTION



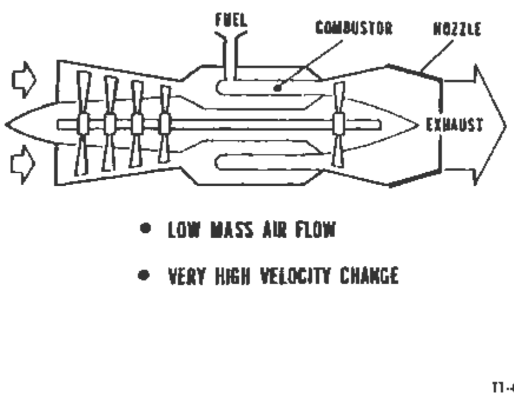
#9

We can apply Newton's Law to the amount of air moving through an engine and arrive at the following conclusion. Thrust is a function of how much air is moved by the engine per second and how much the velocity changes.

Jet engines are sized by the amount of air they move per second--unlike reciprocating engines which utilize total piston displacement. For example, a Rolls Royce Dart turbine engine has a total through-flow of 24 pounds of air per second. This indicates the general size of the engine.

As you will see later, the TPE331-10 Engine has a total through-flow of approximately eight pounds of air per second.

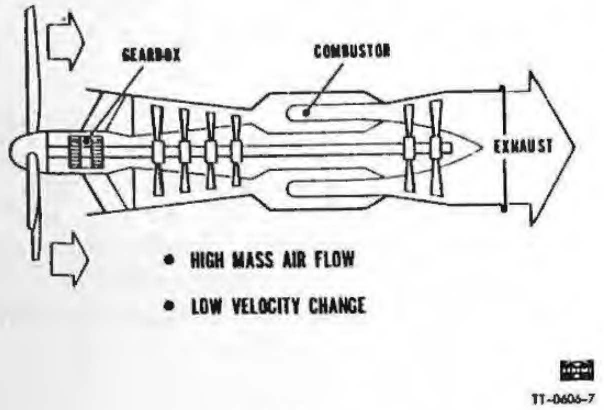
BASIC TURBOJET ENGINE



#10

Let's take a closer look at the three methods of conversion mentioned earlier. The turbojet engine--often referred to as "Purejet"--is an engine with a small cross-sectional area. It flows a relatively small mass at high velocity change. It is used on aircraft which fly at high altitudes and high speeds.

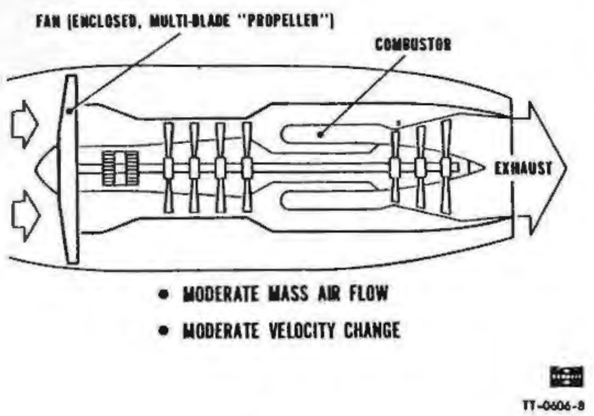
BASIC TURBOPROP ENGINE



#11

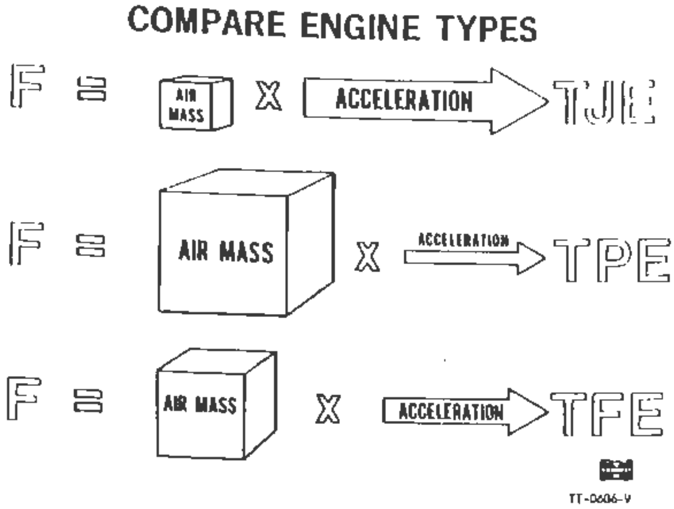
Most of the power of the turboprop engine, shown here, is converted by a gearbox to drive a propeller. The propeller moves a large mass at a low velocity change. The turboprop application is utilized on aircraft which fly at lower altitudes and require better short field capabilities.

BASIC TURBOFAN ENGINE



#12

The turbofan engine is a compromise between the best features of the turbojet and turboprop engines. This combination results in better high altitude performance than the TPE and better low altitude performance than the TJE.



#13

In this illustration, Newton's Second Law--force equals air mass times acceleration--is applied to a comparison of the three types of engine.

Notice that the turbojet equation consists of a small air mass times a high acceleration, while the turboprop involves a larger air mass times a lesser acceleration. The turbofan is a compromise between the other two applications.

ENGINE CHARACTERISTICS

TURBOJET:
LOW MASS AIRFLOW, HIGH VELOCITY CHANGE-
NOISY. GOOD AT HIGH ALTITUDES, HIGH AIRSPEEDS.

TURBOPROP:
HIGH MASS AIR FLOW, LOW VELOCITY CHANGE,
GOOD AT LOW ALTITUDE AND LOW AIRSPEEDS.

TURBOFAN:
MODERATE MASS AIR FLOW AND VELOCITY CHANGE.
MODERATE THRUST AND FUEL CONSUMPTION AT
ALL AIRSPEEDS AND ALTITUDES. LOW NOISE.

TT-0606-10

#14

When choosing an engine, the airframe manufacturer must consider advantages and disadvantages in light of the expected aircraft performance.

For example, suppose an airframe manufacturer had an aircraft destined for use in the General Aviation or Corporate Executive market. He might decide that the ability to operate from small airports is more important than cruise speed. Looking at this chart, we can see that the turbojet application would not be suitable with its emphasis on high altitude and airspeed performance. The turboprop, however, would be the ideal choice. It's high mass airflow and low velocity change make it more efficient than the turbojet at low altitudes and low airspeeds.

POWER SELECTION

TYPE OF TURBINE POWER DEPENDS ON AIRCRAFT:

- MISSION
- SIZE
- SPEED
- COST
- PERFORMANCE

MANY MODERN AIRCRAFT USE TURBOPROP POWER

TT-0506-11

#15

The turboprop powered aircraft is one of the fastest growing markets in the General Aviation and Executive Aircraft field. Some examples of aircraft utilizing the TPE331 Engine application are:

Rockwell Commander 690
Beech B100
Cessna Conquest
Fairchild Porter
Mitsubishi MU2
Short Brothers Skyvan
Swearingen Metro
Rockwell Commander Thrush
Casa 212
Handley Page Jetstream
North American Rockwell OV10D

The TPE331-10 Engine was certified in 1978 to 900 horsepower. The design capability of this engine permits the -11 version to be certified to 1,000 horsepower.

The history preceeding the introduction of the -10 engine reveals several interesting numbers. For instance, a total of over 6,000 TPE331 Engines had been delivered by 1979. These engines are used on 50 different models--including the examples listed above--operating in 63 different countries. The TPE331 Engines had accumulated 13,000,000 flight hours by 1979. It is this kind of experience that allows us to introduce the TPE331-10 with an initial recommended time between overhauls of 3,000 hours.

TPE331 DESCRIPTION

- 575 TO 1000 HP CLASS TURBOPROP ENGINE
  - RUGGED AND RELIABLE DESIGN
    - SINGLE SHAFT CYCLE
      - INTEGRAL GEARBOX
        - TWO STAGE CENTRIFUGAL COMPRESSOR
          - THREE STAGE AXIAL TURBINE
            - SINGLE ANNULAR COMBUSTION CHAMBER

TT-0606-12

#28

All of the items on this list will be explained in greater detail in subsequent sections of this book. At this point, it is sufficient to say that 331 Engines are rugged and reliable due to the integral gearbox, two-stage centrifugal compressor, three-stage axial turbine and single annular combustion chamber and--as a result of the single shaft cycle--power response is instantaneous.

IDENTIFICATION

TYPICAL MODEL NUMBER TPE331-10U-501G

TPE = TURBOPROP ENGINE
331 = ENGINE MFR SERIES INDICATOR
-10 = POWER CLASS (CERTIFICATION)
U = INLET UP
-501 = CONFIGURATION
G = APPLICATION-AIRCRAFT MFG.

TT-0606-13

#29

Each engine will have a nameplate attached to the gearbox. In order to properly identify each engine, it will be necessary for you to understand the breakdown of the model number on that nameplate. Let's use TPE331-10 U-501-G as an example.

TPE, as you already know, stands for turboprop engine. 331 is a series indicator assigned by the engine manufacturer. The -10 identifies the power class as certified by the FAA. The letter "U" indicates the inlet is up in this engine configuration. If no letter "U" appears in the model number, the inlet will be on the bottom. This depends on the individual aircraft installation. The -501 is an indication of the engine configuration, that is, the specific location and configuration of components. Finally, the "G" is used to identify the aircraft installation. In this example, the "G" stands for the Swearingen Aircraft Company.

HORSEPOWER DEFINITIONS

SHAFT HP (SHP) = POWER AVAILABLE TO PROP

EQUIVALENT SHP (ESHP) = SHP PLUS THE THRUST PRODUCED BY THE EXHAUST DISCHARGE CONVERTED TO THE EQUIVALENT SHP IT REPRESENTS AT A STATIC CONDITION

$$\text{ESHP} = \text{SHP} + \frac{\text{NET THRUST (LB)}}{\text{FACTOR (AFFECTED BY PROP)}}$$

71-0606-14

#30

Now let's examine some of the terms commonly used when describing performance ratings of the 331 Engine.

The term, "Shaft Horsepower" is used to identify the power available to drive the propeller.

"Equivalent Shaft Horsepower," or "ESHP," is the result of adding net exhaust thrust to the shaft horsepower. This value would be of primary interest to the airframe designer, recognizing that exhaust thrust will contribute to the takeoff performance of the aircraft.

As the aircraft increases in speed, exhaust thrust becomes negligible. The only time ESHP becomes important to the operator is when comparing horsepower ratings of various engines. Make sure your terminology is the same. It is not meaningful to compare shaft horsepower to equivalent shaft horsepower! You will see why when we look at the specific fuel consumption that an engine will burn to produce a given horsepower rating.

TPE331 RATING VALUES - DEFINITION

THERMODYNAMIC S.H.P./E.S.H.P.

HP CAPABILITY OF THE ENGINE'S
POWER SECTION WHEN OPERATING AT
MAXIMUM PERMITTED TURBINE INLET TEMPERATURE
AT STANDARD SEA LEVEL CONDITIONS

TT-0606-18

#31

The term that is used to identify the maximum power capability of a given engine is "Thermodynamic Horsepower Rating."

This rating identifies the maximum power capability of that engine's power section when operating at a maximum turbine inlet temperature at standard sea level conditions.

FLAT RATING

ENGINES HAVING A GREATER THERMODYNAMIC POWER CAPABILITY THAN REQUIRED FOR THE DESIGNED AIRCRAFT PERFORMANCE ARE OFTEN SELECTED. THESE "OVERSIZED" ENGINES ARE THEN CERTIFIED TO THE FLAT RATED VALUE IN THEIR SPECIFIC INSTALLATION.

BENEFITS FROM USING FLAT RATED ENGINES:

- LOWER TURBINE TEMPERATURES AT TAKEOFF
- IMPROVED ALTITUDE PERFORMANCE
- LONGER ENGINE LIFE

TT-0606-15

#32

When an aircraft designer selects the power necessary to make his aircraft perform according to design specifications, he will often select an engine that is oversize in its capability and then limit the power to that required by the aircraft. This is know as "Flat Rating" the engine.

One of the major benefits of using a flat rated engine is the ability to obtain takeoff power at a lower turbine inlet temperature. Other benefits include improved altitude performance and longer engine life.

FUEL CONSUMPTION - DEFINITION

SFC = SPECIFIC FUEL CONSUMPTION

MEASURED AS LBS (FUEL) PER H.P. PER HOUR

SFC (LB/HP/HR) X HP = P.P.H. (LBS PER HOUR)

TT-0606-16

#33

One of the important considerations when rating an engine is the amount of fuel it will burn to produce the required horsepower. This is known as the "Specific Fuel Consumption" or "SFC."

Typical fuel flow indicating systems in a 331 powered aircraft measure the volume of fuel being used and are calibrated in pounds per hour or PPH.

It can be seen from the formula pictured here--specific fuel consumption in pounds per horsepower per hour multiplied by the horsepower being produced--would result in a figure for total pounds per hour.

Obviously, the engine that can produce one horsepower for each hour at the lowest fuel flow would be the most efficient in converting fuel energy into useable shaft horsepower.

PERFORMANCE RATINGS - TPE331 MODELS

MODEL	-1	-2	-3	-5/-6	-8	-9	-10	-11
TAKEOFF (ESHP/SHP)	705/665 (1)	755/715	904/840	776/715 (2)	755/715 (3)	907/865	944/900 (4)	1045/ 1000
THERMO DYNAMIC (ESHP/SHP)	755/715	755/715	904/840	904/840	907/865	907/865	1045/ 1000	1045/ 1000
ESFC (TAKEOFF)	0.571	0.558	0.548	0.57	0.57	0.54	0.55	0.53

(1) TO 75°F (2) TO 92°F (3) TO 97°F (4) TO 80°F

TT-0606-19

#34

This chart shows the performance ratings of the -1 through -11 Garrett TPE331 Engines. Note that both ESHP and SHP values are given for takeoff and thermodynamic ratings. Notice also that specific fuel consumption is given as "ESFC." This means fuel consumption is calculated using the equivalent shaft horsepower as a rating.

Look at thermodynamic ratings. The -1 and -2 models have identical thermodynamic ratings. We can see that the -3, -5 and -6 engines are also thermodynamically identical. The -8 and -9 models have matching ratings, too. Finally, the -10 and -11 engines have the exact same thermodynamic ratings.

What all of this means is that the Garrett Turbine Engine Company builds four basic sizes of turboprop engines as indicated by their thermodynamic rating capability. These engines are certified into 11 different dash numbers so operators will observe takeoff power limits established on each engine installation as approved by FAA certification.

SECTION TWO:

GARRETT PUBLICATIONS

PUBLICATION PRIORITY

FAA APPROVED DOCUMENTS

1. AIRCRAFT FLIGHT MANUAL (P.O.M.)
2. AIRCRAFT MANUALS
   MAINTENANCE
   OVERHAUL
   TEMPORARY REVISIONS
   SERVICE BULLETINS
3. ENGINE MANUALS
   MAINTENANCE
   OVERHAUL
   ILLUSTRATED PARTS CATALOG
   TEMPORARY REVISIONS
   SERVICE BULLETINS

TT-0607-3R

#38

Garrett provides a variety of publications to the owner/operator. These include Maintenance Manuals, Overhaul Manuals, Illustrated Parts Catalogs, Engine Logs, Training Manuals and various Service Information Documents. These publications may also be provided in microfiche form.

It is important for the maintenance technician to recognize the priority of FAA approved documents as they apply to the operation and maintenance of his aircraft. The importance of recognizing this priority has to do with resolving any conflict that may exist between information contained in various publications.

In all cases, the Aircraft Flight Manual--sometimes called, "Pilot's Operating Handbook" or "Manual"--is number one in priority. Next in line are the Aircraft Manuals. Third in priority in this sequence are the FAA approved Engine Manuals.

This priority sequence is particularly important when we consider general service information or training material that conflicts with FAA approved document statements. The FAA approved documents are considered to be correct.

Remember, training information presented in this book has no official status.

Now let's take a closer look at some of the publications mentioned on this list.

ENGINE MAINTENANCE MANUAL

SUBJECTS COVERED:

DESCRIPTION AND OPERATION
TROUBLESHOOTING
MAINTENANCE PRACTICES
SERVICING
REMOVAL/INSTALLATION
ADJUSTMENT/TEST
INSPECTION/CHECK
CLEANING/PAINTING
APPROVED REPAIR

TF-0607-4

#39

Aircraft manuals will usually refer the operator to the engine manufacturer's maintenance manual for detailed instructions relative to maintaining 331 Engines. This list identifies subjects typically covered in the engine maintenance manuals.

These subjects are located in the maintenance manual through the use of an ATA 100 Numbering System. This is a specification developed by the Airline Transport Association to maintain consistency and standardization in aircraft and engine manuals. Instructions for using the numbering system are located in each manual.

ILLUSTRATED PARTS CATALOG

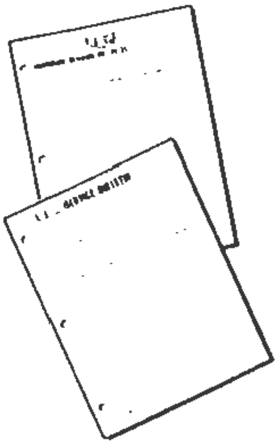
- IDENTIFIES DETAIL PART NUMBERS TO THE LEVEL OF MAINTENANCE DESCRIBED IN THE MAINTENANCE MANUAL
- PROVIDES APPLICABLE PUBLICATIONS LIST OF COMBINED OVERHAUL/IPC MANUALS FOR DETAILS BEYOND NORMAL MAINTENANCE LEVELS

TF-0607-5

#40

The illustrated parts catalog serves a dual purpose. First, it provides detailed part numbers necessary for performing maintenance actions. Second, it contains a list of publications covering overhaul and parts information on components. This list of publications can also be found in the maintenance manuals.

MANUAL REVISIONS/BULLETINS



ADVANCE NOTICE OF CHANGES THAT WILL BE INCLUDED IN PERIODIC REPRINTS OF MAINTENANCE, OVERHAUL AND ILLUSTRATED PARTS MANUALS

TT-0607-6

#41

Temporary revisions and service bulletins are FAA approved advance notices to changes in the manuals. The information in these notices will be incorporated into the manuals at time of revision, but it is imperative to good maintenance practice to add it to your engine records and manuals when first received.

CUSTOMER ENGINE MANUALS

EACH NEW AIRCRAFT DELIVERY INCLUDES:

- ONE MAINTENANCE MANUAL
- ONE ILLUSTRATED PARTS CATALOG
- ONE LOG BOOK FOR EACH ENGINE

ENGINE WARRANTY CARDS SENT TO GARRETT RESULT IN:

- MANUAL REVISIONS, SERVICE BULLETINS AND RELATED SERVICE INFORMATION AS LONG AS YOU OWN THAT AIRCRAFT

TT-0607-7R

#42

Most aircraft manufacturers will include one copy each of the engine maintenance manual and illustrated parts catalog, and one engine log book for each engine, with delivery of the new aircraft.

It is very important for the owner of the new aircraft to complete the warranty cards included in the engine log books and send them to Garrett. He is then guaranteed to receive manual revisions, service bulletins and related service information for as long as he owns the aircraft.

In the event that a second owner of the aircraft does not get the manuals originally issued with the aircraft, he may buy new manuals and subscribe to a revision service by contacting Garrett Product Support.

INFORMATIONAL MATERIAL

SERVICE DOCUMENTS WITH NO OFFICIAL STATUS:

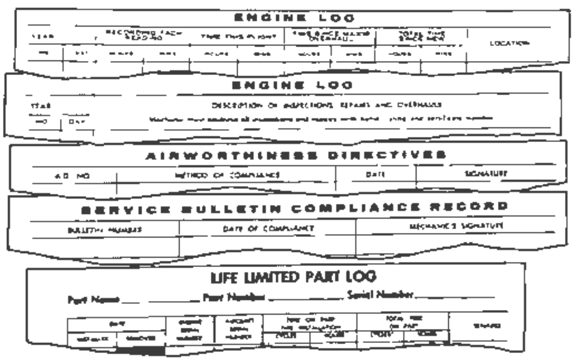
- ENGINE LOG BOOKS
- SERVICE INFORMATION LETTERS
- OPERATING INSTRUCTIONS
- NEWSLETTERS
- TURBINE TIPS AND TOPICS
- TRAINING MATERIAL

#44

This chart lists the typical service documents the owner will receive. It is important to keep in mind that these publications are not FAA approved.

The engine log book is provided for recording maintenance actions and hours of operation. The remainder of the listed items, issued by the Garrett Product Support and Field Service Departments, are informative in nature and are designed to help the operator obtain the best possible service from his TPE331 Engine.

ENGINE LOG BOOK



TT-0607-10

#45

Accurate and complete records of engine maintenance and service are a vital part of efficient maintenance. This illustration shows the typical subject identification on the various pages within the engine log.

The top two pages shown are used for recording the time since new, the time since major overhaul and the description of inspections, repairs and overhauls that are accomplished on the engine.

The next page shown is a record of compliance to airworthiness directives, followed by a page used for recording service bulletin compliance, and a life limited part log for those parts for which time in use must be kept. The three turbine wheels are an excellent example of life limited parts.

The importance of record keeping can best be illustrated by noting that in the life limited part log, there is a place for recording the number of hours or the cycles that a given part has accumulated. It is to the advantage of most operators to record their engine time in cycles.

ENGINE CYCLE DEFINITION

AN ENGINE OPERATING SEQUENCE CONSISTING OF:

- ENGINE START
- TAKEOFF
- LANDING
- ENGINE SHUTDOWN

= ONE CYCLE

TT-0607-14

#46

One cycle is recorded as an engine operating sequence consisting of an engine start, takeoff, landing and engine shutdown. It is recognized that some engine runs will not be counted as a cycle under this definition.

For example, if the mechanic does an engine run to check out maintenance actions, this would not be counted as a cycle because he does not complete the takeoff portion of the cycle definition.

Since the basis for a cycle is related to the thermal shock to the high temperature parts, it would be impractical to attempt to record all ground operations as having an equally detrimental effect on engine life. The average effect of ground operation is taken into consideration when determining the cycles between major maintenance actions.

SERVICE TIPS

INFORMATIVE SUGGESTIONS AND RELATED INFORMATION DISTRIBUTED BY GARRETT CUSTOMER SERVICE ENGINEERING:

- SERVICE INFORMATION LETTERS (S.I.L.)
- OPERATION INSTRUCTIONS (O.I.)
- TURBINE TIPS AND TOPICS
- NEWSLETTERS

TT-0607-11R

#47

The publications noted on this list are distributed to the aircraft operator by the Garrett Customer Service Engineering Department. They are used primarily to give each operator the benefit of the shared experiences of all operators. The material is usually technical, but may also include subjects of general information.

TRAINING MATERIAL

MATERIAL USED IN FACTORY TRAINING PROGRAMS IS REPRESENTATIVE ONLY AND SHOULD BE USED SOLELY FOR TRAINING PURPOSES:

- STUDY GUIDES
- TYPICAL ENGINE RUN SHEETS
- VISUAL AIDS
- WORKBOOKS

#48

It must be emphasized at this point that training material produced by the Garrett Technical Training Center in Phoenix for customer, pilot, and maintenance personnel is for TRAINING PURPOSES ONLY. This material is representative and should not be used in lieu of the official FAA approved publications.

WORKBOOK EXERCISE 1

SUBJECT:
SECTION 1 - DESCRIPTION AND RATINGS

SECTION 2 - PUBLICATIONS

1. Which of the following is true of the turboprop engine?

   a. Moderate mass airflow with a moderate velocity change.
   b. High mass airflow with a low velocity change.
   c. Low mass airflow with a very high velocity change.

2. Describe the turbine section of the TPE331 engine.

   a. Two stage radial.
   b. Three stage radial.
   c. Two stage axial.
   d. Three stage axial.

3. The position of the compressor inlet of a TPE331-10-501C is:

   a. Above the engine centerline.
   b. Below the engine centerline.

4. Equivalent shaft horsepower is:

   a. The shaft horsepower plus the effect of jet thrust.
   b. Valid only at cruise speed.
   c. The power delivered to the propeller.

5. Flat rating is best described by which of the following statements?

   a. Certifying the engine installation to the thermodynamic capability of the engine power section.
   b. Certifying the engine installation to a horsepower value less than the thermodynamic capability of the engine power section.

6. What is the correct method of obtaining future manual revisions and other related documents after the purchase of a new aircraft?

   a. Return the completed engine warranty cards to the Garrett Turbine Engine Company.
   b. Contact the airframe manufacturer.
   c. Contact your local field service representative.
   d. Contact the Training Department.

WORKBOOK EXERCISE 1

7. From the following lists, select the one which contains only FAA approved documents.

   a. Maintenance Manual, Illustrated Parts Catalog, Service Bulletins, Operating Instructions.
   b. Maintenance Manual, Temporary Revisions, Service Bulletins.
   c. Maintenance Manual, Log Book, Illustrated Parts Catalog, Service Information Letter.
   d. Maintenance Manual, Training Manual, Temporary Revisions, Service Bulletins.

8. How many cycles would you enter into the log book after completing three static takeoff power checks for the purpose of maintenance adjustment?

   a. 3 cycles.
   b. 2 cycles.
   c. 1 cycle.
   d. No cycle entry required.

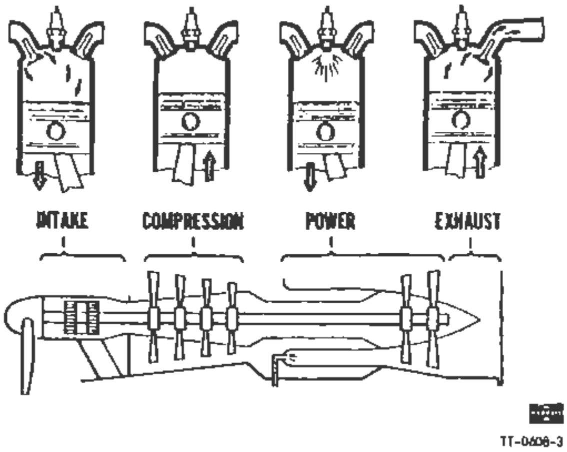
9. If an engine having a specific fuel consumption of 0.540 lbs./shp./hr. is producing 900 shp, how many pounds of fuel per hour are being used?

   a. 463 PPH
   b. 486 PPH
   c. 510 PPH
   d. 534 PPH

SECTION THREE:

THEORY OF OPERATION

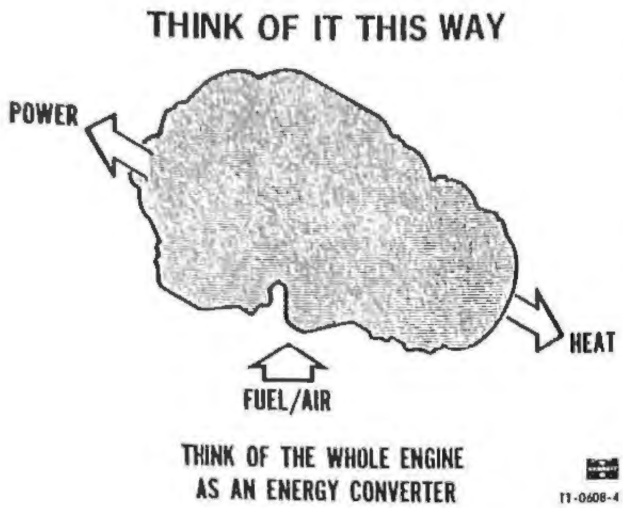
PISTON vs TPE WORKING CYCLE



#52

All turbine engines are air breathing engines. The turbine engine working cycle can be compared to something already familiar. Consider the typical four stroke cycle reciprocating engine, which is illustrated here by the major events that occur in one complete cycle. As the piston on the left moves down on the intake stroke, a fuel/air mixture enters the combustion chamber. In the second view, the piston moving up is in the act of compressing that mixture. With the advent of ignition in the third picture, the piston moves down in what is known as the power stroke. During the power stroke, the gaseous energy is converted into rotational shaft horsepower by the action of the piston, the crank shaft and the connecting rod. The final action is the exhaust stroke, where the air is returned to atmosphere.

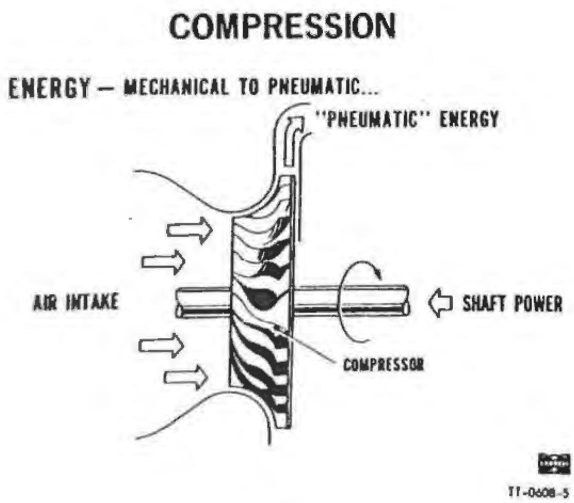
As we examine the schematic of the turboprop engine, we see that the same functions are performed by the intake, compression and power sections, where the power is extracted and converted to mechanical shaft energy. The exhaust gases are discharged to the atmosphere. We will now follow this sequence as we describe the working cycle and construction of the 331 Engine.



#53

Before we concern ourselves with the details of how the engine does what it does, it is important that we recognize the basic function of the turboprop engine. It can most simply be stated as being an energy device that can convert the chemical energy of a supply of fuel into a useable horsepower (a mechanical energy). If this engine were 100% efficient as an energy converter, then the entire energy represented by the fuel would be converted to horsepower. Since no mechanical device is 100% efficient, then obviously some of the fuel energy will escape in the form of heat.

It is important at this point to remember a truth we learned in school. Energy can be neither created nor destroyed but, can be converted from one form to another. That's exactly what the turboprop engine does. It converts the energy represented by the fuel into useable power and heat energy.



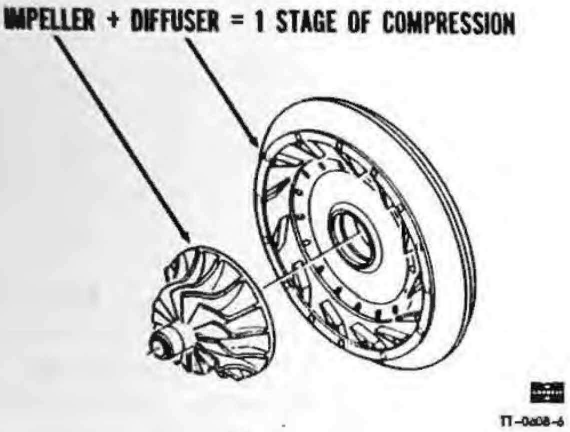
#54

The compressor performs both the intake and compression portions of the four stroke cycle reviewed previously. As the compressor impeller is rotated, it draws air into the inlet portion and discharges it with high velocity at the outer periphery of the wheel. This creates a low pressure area at the inlet, so that more air is drawn in.

The TPE331 utilizes a centrifugal compressor, rather than the axial compressor used in some engines. The principal advantage of a centrifugal compressor is its designed resistance to foreign object damage. Most large foreign objects are rejected at the first stage compressor due to impeller speed and centrifugal geometry.

Nominal erosion due to small particles is not a significant factor because of rugged construction of the TPE331 Compressor. The ruggedness of the centrifugal wheel and its resistance to foreign object damage is a substantial contributing factor to long life and low cost of operation.

COMPRESSION STAGE

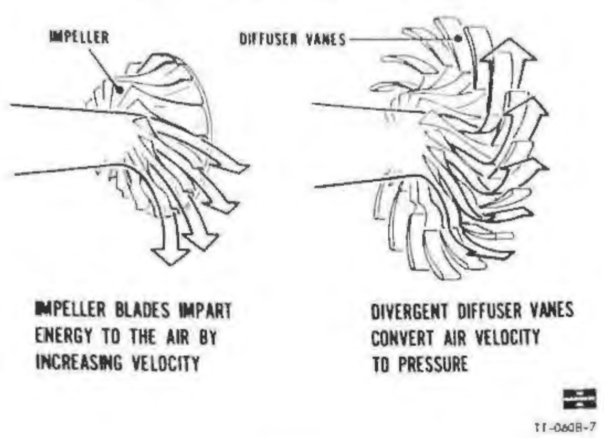


#55

This picture identifies the two major components necessary for any stage of compression--the centrifugal impeller and a diffuser. The importance of the diffuser can be realized when we remember that the impeller takes the ambient air and increases it to a high velocity. This high velocity air then flows through the diffuser vanes as shown. In the diffuser and crossover duct assembly, the vanes are divergent nozzles, that is, the cross-section area increases as the distance from the vane inlet to the discharge increases. This divergent duct causes the high velocity air to slow down and increase in pressure.

The combination of one impeller and its diffuser equals a single stage of compression. In this case, the diffuser also acts as a crossover duct to carry that air into the entrance of another impeller and diffuser which provides a second stage of compression. The compressor section of the TPE331 can thus be described as a two stage centrifugal compressor section. The pressure increase from ambient to compressor discharge is an approximate 10 to 1 pressure ratio. This pressure ratio represents the contribution in pneumatic energy by the compressor section to the engine power cycle. The compressor moves a total volume of approximately eight pounds of air per second.

COMPRESSION STAGE

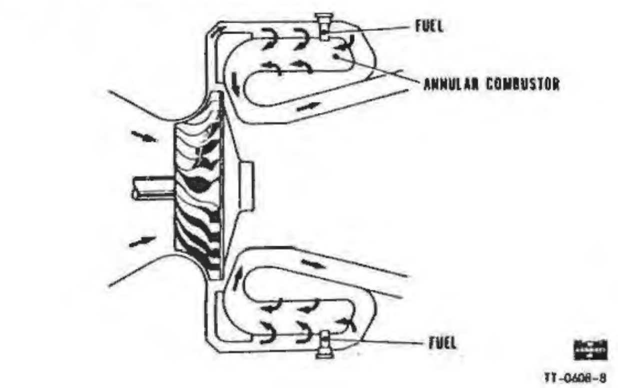


#56

These pictures better illustrate the flow of air being thrown outward through the compressor impeller blades where its velocity will be increased. That air then flows through the vanes of the diffuser where that high velocity will be converted into pressure.

COMBUSTION SECTION

TO ADD THERMAL ENERGY...

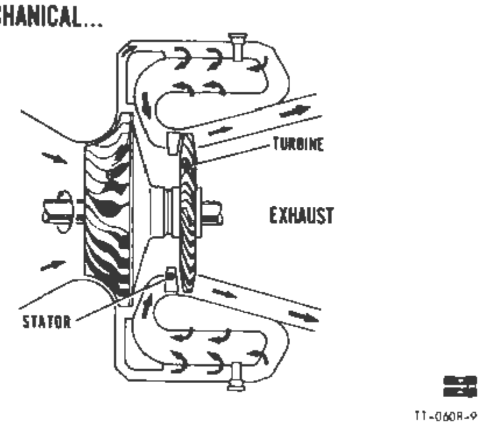


#57

This high pressure air from the compressor discharge is then directed to flow through an annular combustion chamber. At this point in the cycle, fuel is added and the fuel/air mixture is ignited by a spark from the ignition system during the engine start procedure. Burning the fuel/air mixture in the combustion section results in raising the level of pneumatic energy. This causes an increase in the velocity of the gases as they leave the combustion section. We will explain in a later section how controlling this fuel being added to the combustion section regulates the power produced by the engine.

POWER EXTRACTION

THE TURBINE WHEEL CONVERTS PNEUMATIC ENERGY TO MECHANICAL...



#58

The power stroke in the four cycle reciprocating engine utilizes the energy created by the expansion of hot gases to press the piston down and convert that pneumatic energy into a rotational horsepower or mechanical energy. In the 331 Turbine, this power extraction is accomplished by the turbine wheels.

Hot gases from the combustion chamber entering the turbine section first pass through a stator, or stationary member, which causes those gases to increase in velocity through the converging design of the stator nozzles. That air is then directed to impinge upon the blades of the turbine wheel, causing the wheel to rotate at high speeds. As the hot gases leave the turbine section, they are vented to the exhaust, thereby, completing the cycle.

The high speed rotational torque of the turbine wheel is directly connected to drive the compressor. It is interesting to note that approximately 2/3 of the power produced by a turbine section in a jet engine is required to drive the engine's compressor section.

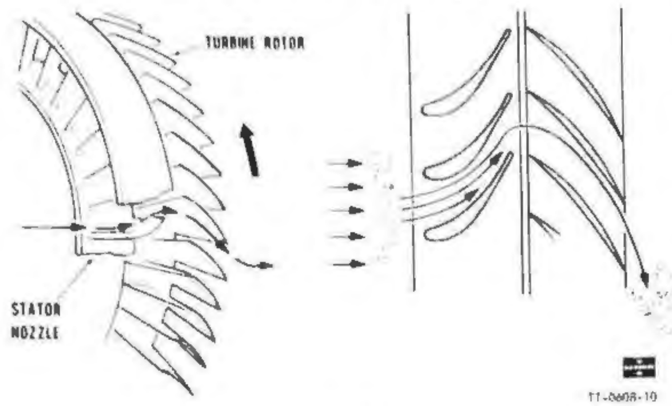
Excess power that is produced above that requirement may be used to drive propellers or to create thrust.

The compressor, combustor, and turbine are often referred to as the "Gas Generator." The gas generator is that portion of the jet engine that converts fuel energy into high speed rotational mechanical power.

At this point in the cycle the engine will provide no useful function because it does not provide the useful power.

TURBINE STAGE

NOZZLE + ROTOR = 1 TURBINE STAGE



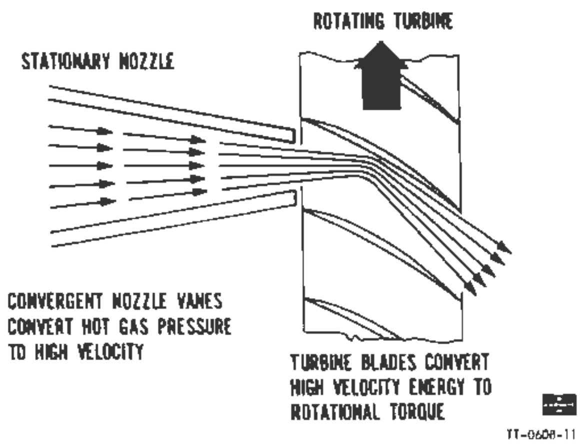
#59

Each turbine stage consists of a nozzle assembly and a rotor assembly, occasionally referred to as a stator and turbine wheel, respectively. This turbine stage is very similar to the combination of rotating and fixed parts seen in the compressor section. However, in this case we are not concerned with compression, but rather, extracting power.

The picture on the left identifies the stator nozzle assembly with its stationary vanes. These vanes are positioned at an angle that causes the air passing through them to impinge upon the rotating element blade at the appropriate angle and with the maximum velocity attainable.

The picture on the right shows the airflow through the nozzle vanes being directed to impinge upon the rotating vanes of the turbine wheel, thereby, causing the turbine to rotate. The combination of one nozzle assembly and one wheel is identified as one turbine stage.

TURBINE STAGE

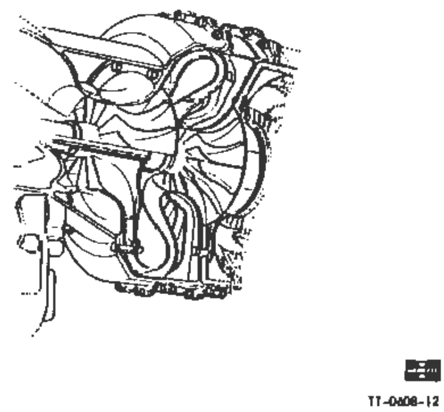


#60

In this drawing, the nozzle assembly shown on the left is a convergent duct that causes the hot gas pressures to increase in velocity. Secondary purpose of the nozzle is to direct those high velocity gases at the appropriate angle where the air enters the turbine wheel.

The turbine wheel on the right shows the air impinging off of the blades. This action converts the high velocity energy to rotational torque. It is a law of physics that any body in motion tends to remain in motion and resists changing in direction. The laws of physics also tell us that each action has an equal and opposite reaction. The action of the air impinging on the turbine wheels results in a reaction causing the turbine wheel to rotate in the direction of the arrow.

TWO STAGE COMPRESSOR



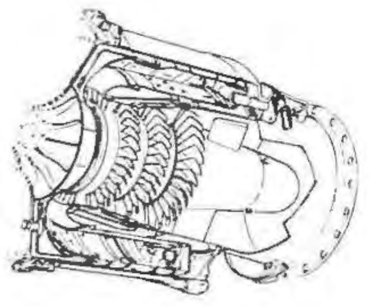
#61

Since we have now covered the theory of operation of the gas generator components, it might be useful to look at some of the actual hardware so we can recognize the components that we described.

This is a picture of the compressor section of the 331 Engine. In this case, the air enters from the inlet duct in the upper left hand corner. That air is available to the front face of the first stage compressor. Notice that the discharge of that wheel goes through the diffuser crossover duct section and presents itself to the inlet of the second stage compressor wheel. As the air is further compressed and increased in velocity through that second wheel, it enters the diffuser section in the passages leading from the second stage compressor wheel. The compressor discharge air then enters the cavity known as the "Plenum Chamber."

Looking at the compressor picture, we can see that it would be a relatively simple task to inspect the leading edges of the first stage compressor impeller. On all 331 Engine applications, this is possible by looking into the inlet of the engine. With a good light, you can see and inspect the leading edge of the first stage impeller blade. Obviously, you would be looking for indications of foreign object damage resulting in nicks, dents or bent blades. This would be accomplished at a preflight inspection.

COMBUSTOR AND 3 STAGE TURBINE



TT-0608-13

#62

On the left side of this picture, the second stage compressor impeller can still be seen and, as we trace the flow of air through the diffuser section, we can see that air completely fills the plenum chamber section. The air is then available to the annular combustion chamber. This is the device with all of the holes in it. As the air flows through these holes into the combustion chamber, it is mixed with the fuel being sprayed from the fuel atomizers. This combustion chamber is often referred to as a "Reverse Flow Annular Combustion Chamber." The air now flows toward the front of the engine. The hot gas enters the transition liner, where it rotates or turns 180°, and presents itself to the first stage of the turbine section. Air passing through the first stage stator enters the first stage turbine wheel where power is extracted.

As the burning gases leave the first stage turbine wheel, they pass through the second stage stator assembly. This stator assembly again straightens the air out for maximum efficiency at an angle at which it impinges upon the turbine blades and also increases the velocity through the convergent duct action of the stator assembly. The air then continues through the third stage stator assembly and third stage turbine. Discharge from the third stage is then ducted out through the exhaust duct to atmosphere.

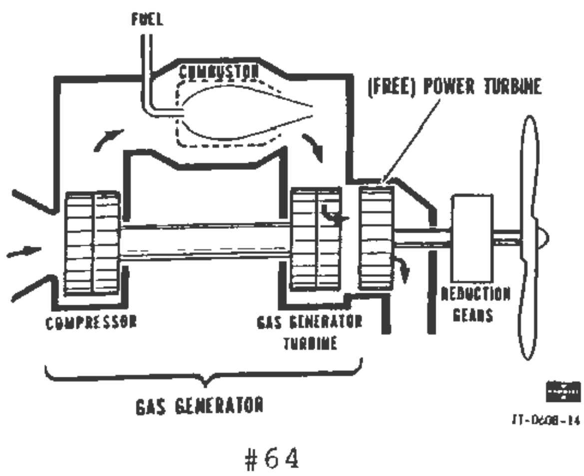
It will be noted that the turbine wheel stages are in three different sizes. The first stage is the smallest in diameter, the second stage increases in diameter, and the third increases to become the largest of the three. This difference in sizes is intentionally designed to share the load of the power extracted by each stage of the turbine. The pressures and temperatures felt at the first stage are obviously higher than they would be after passing through the stage where both temperature and pressure drops. The bigger wheel is now able to take the lesser energy level and extract essentially the same amount of power. The same is true of the third stage.

It was previously stated that approximately 2/3 of the power produced by this turbine section is used within the engine to drive the compressor section. It is interesting to note that to develop an excess power capability of 900 horsepower to drive a propeller, this turbine must produce approximately 3,000 horsepower.

The main rotating assembly of the 331 Engine is the heart of the engine. The two stage radial compressors and three stage axial flow turbines are mounted on a common shaft and are connected by curvic couplings. Each wheel has curvic teeth ground on the hub of the wheel. These are very precise gear teeth on a horizontal plane. As the wheels are stacked together, the curvic teeth are meshed. A through bolt with a nut is tightened to hold these wheels together as one unit.

Labyrinth seals are located at various places on the shaft. These knife edge seals are used to separate the pressures between stages. This rotating group is supported by two bearings, one at the compressor end and one at the turbine end. This assembly rotates at a normal 41,730 rpm when the engine is running at 100% speed.

POWER CONVERSION - FREE



#64

Here we can see the previously described gas generator, consisting of the compressor, combustor and turbine sections. As previously stated, the gas generator provides no useful function other than converting fuel energy into high speed rotational energy. We now must consider the conversion of this energy into a useable form of power.

In the turboprop engine, we are interested in driving a propeller. One method of doing this is referred to as "Free-Turbine." This is accomplished by inserting another turbine wheel in the exhaust discharge from the gas generator path. This extra turbine wheel is referred to as the "Power Turbine."

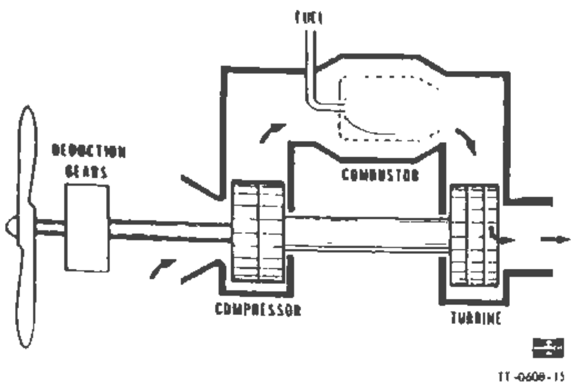
By providing heat energy above and beyond the gas generator requirements, an excess energy is made available to flow through the power turbine. Once again, a stator and turbine assembly are used. This high speed rotational energy is then transmitted to a gearbox where the high speed low torque of the power turbine is converted into a low speed high torque, in order to drive a propeller.

This method of power conversion offers several advantages. It is particularly useful in a helicopter application because the fluidic connection between the gas generator and power turbine greatly simplifies the clutching problems.

Another advantage with this fluidic coupling is the ability to run the gas generator at high speeds with the output shaft from the power turbine running at very low speeds. In propeller driven aircraft, the propeller can be kept at a very low rpm and produce very little noise in a taxi condition.

POWER CONVERSION - FIXED

FIXED SHAFT TYPE



#65

Another method of converting the high speed rotational energy from the gas generator into useable shaft horsepower is illustrated here. In this case, the gas generator on the right hand side of the picture, has an additional turbine capability by the addition of a third turbine wheel. This allows the excess energy above and beyond that required for the engine's compressor section to be made available to that same shaft. In a fixed shaft engine, that shaft is mechanically connected to the gearbox so that the high speed low torque rotational energy transmitted into the gearbox can then by converted to a low speed high torque power to drive the propeller.

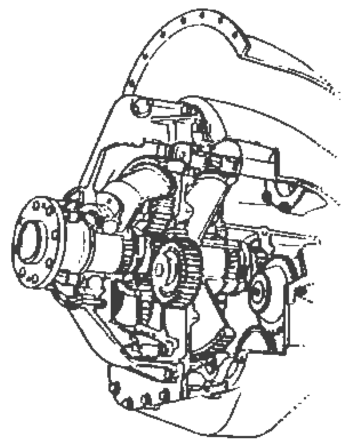
The fixed shaft engine has distinct advantages when it comes to turboprop power for fixed wing aircraft. In order for you to understand the principal advantage, the meaning of several terms must be reviewed. For example, the term "Idle" in all of your previous experience with reciprocating engines is generally used to mean low speed. With the fixed shaft turboprop engine, the term "Idle" means minimum load.

To illustrate this point, let's assume that the propeller in this picture is at a very flat blade angle pitch. Let's further assume that the engine is running at its normal 100% rpm with the gas generator rotating at 41,730 rpm and the propeller rotating at 1,591 rpm. Under these conditions, we would consider the engine to be running at idle. The load would be the minimum load possible. If this engine were asked to produce full power, it would be accomplished by causing the propeller to go to a high blade angle.

Since the engine is already at speed, the response rate of this engine and propeller combination, to go from no power to maximum power, would be limited only by the reaction time of the propeller. This is a characteristic that we refer to as "Instant Response Rate." This is an important advantage of the fixed shaft engine.

Another distinct advantage of fixed shaft type turboprop power is the lower specific fuel consumption. When compared to the free turbine engine, we all recognize that the inefficiencies of the fluidic coupling will cost us power and this relates to fuel consumption. When compared with a free turbine engine on a horsepower to horsepower relationship, the fixed shaft engine will always burn less fuel to produce each horsepower. The TPE331 Engine is of the fixed shaft type.

GEAR SECTION

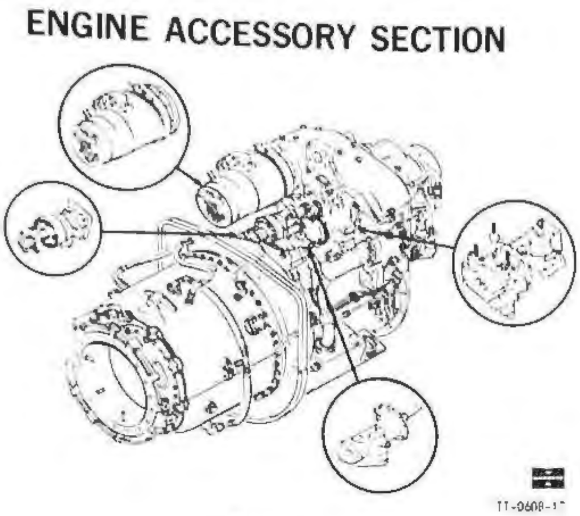


TT-0608-16

#66

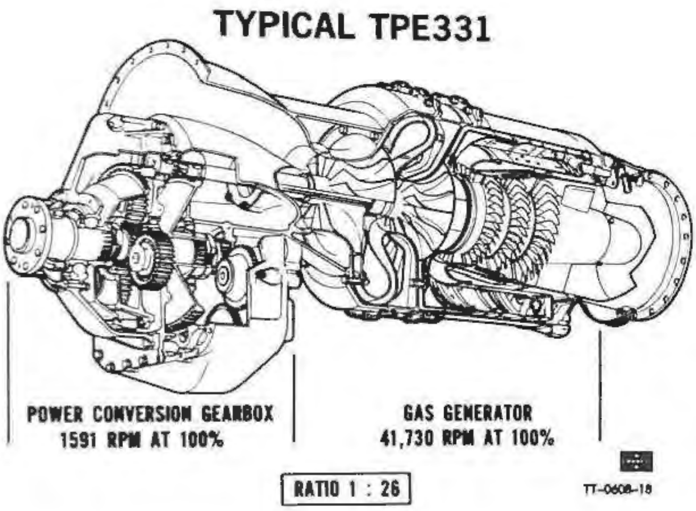
On the TPE331, the gear section has been incorporated and designed into the engine case itself. One of the principal advantages of this design is that the air inlet section can be designed to match the engine. This is a very critical part on any turbine engine. On the top of this picture, you will see the air inlet duct that carries the air to the first stage compressor.

The gearbox itself contains a planetary system converting the 41,730 rpm of the main shaft into the 1,591 rpm of the propeller shaft. This high speed low torque conversion to low speed high torque is accomplished by a gear ratio of approximately 26 to 1. Some models of the 331 utilize a 20 to 1 gearbox ratio to provide 2,000 propeller rpm.



#67

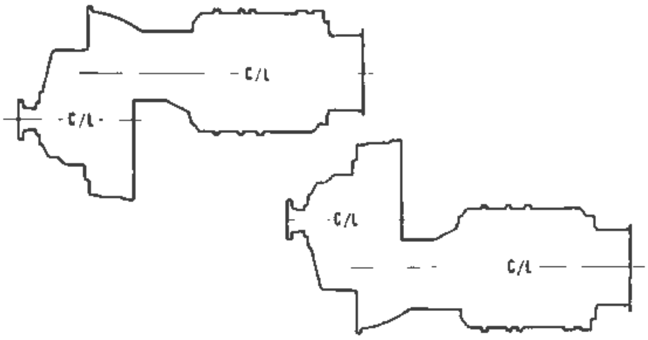
This picture reveals that the engine driven accessories are also handled by the gearbox. The accessory section is on the back face of the main housing. It provides mounting pads for the engine driven accessories as well as places for related control components that are not engine driven.



#68

This cutaway drawing shows the entire engine. The gas generator on the right operates at 41,730 rpm at 100%. The gearbox on the left, with the reduction in speed, operates at 1,591 rpm as a result of the 26 to 1 ratio. Also easily visible on this picture is the inlet duct, which is designed as part of the gearcase itself.

INLET CONFIGURATIONS



AIRCRAFT INSTALLATION OPTION

TT-0608-19

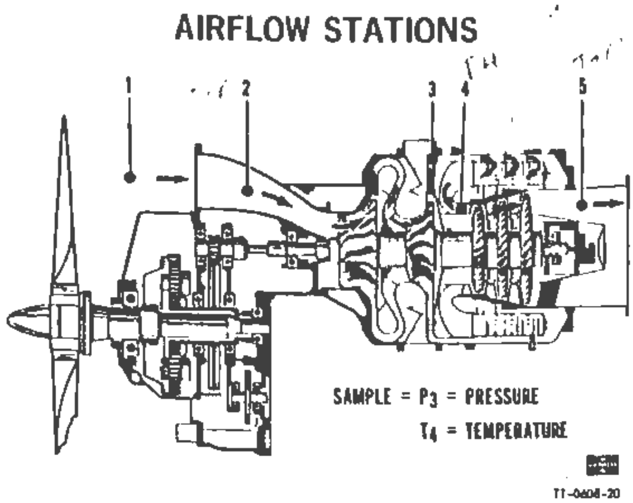
#69

One of the principal installation advantages of the TPE331 is the number of options available to the aircraft designer. Looking at this picture we can see that the inlet may be installed on top of the engine or the gearbox may be rotated so that the inlet is on the bottom. This is a prime concern to the aircraft designer when he considers such things as tip clearance and landing gear length and wing arrangement. For example, if the aircraft has an exceptionally long landing gear and tip clearance is no problem, he probably would select the top version with the inlet on top. This drops the center line of the propeller shaft below the center line of the engine. The advantage will be in getting the inlet farther away from the foreign object material found on the runways.

If the aircraft is a low wing aircraft and the landing gear is short enough to cause a tip clearance problem, he may select the option shown on the bottom. By rotating the gearbox so that the inlet is down, it raises the center line of the propeller shaft above the center line of the engine.

Any model of the 331 ordered from Garrett can be designated to be an inlet up or inlet down configuration. This is not a change that could be made by a mechanic in the field. Obviously, there are considerations for oil sumps, pickup tubes, etc., that would prevent this from being just a matter of rotating the gearbox.

Present applications of the TPE331-10 Engines utilize both inlet up and inlet down configurations. Throughout the rest of this book, you will see examples of both inlet up and inlet down applications.



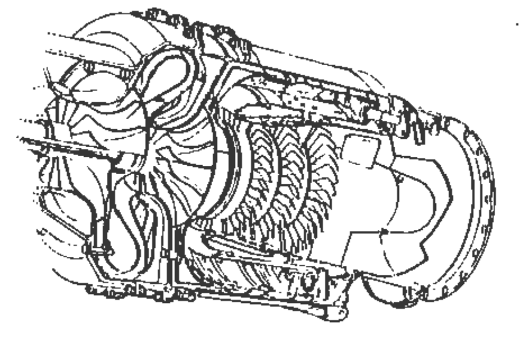
#70

All turbine engine manufacturers utilize a station number identification for ease of description of various functions and locations within the airflow path. This picture shows us that Station Number 1 represents the ambient conditions outside of the engine. Station Number 2 would be the inlet to the compressor section. Station Number 3 is the discharge from the compressor section. Station Number 4 is the inlet to the turbine section. Station Number 5 would be the exhaust discharge downstream of the turbine section.

Combining these numbers with various alphabetical symbols can make it easy to identify various pieces of information. As an example, let us use P3. The letter "P," identifying pressure, and 3, identifying the station number, would designate the pressure at compressor discharge. The term P3 is used frequently in the fuel control system. Another example is T4. "T," of course, stands for temperature, and 4, the station at the inlet to the turbine section. T5 indicates the temperature downstream of the turbine.

Various intermediate points between these main stations can be identified by a decimal point. As an example, Station 2.1 indicates the entry to the second stage compressor. Station T4.1 identifies the temperature at the inlet to the second stage turbine. Station 4.2 would be the entry to the third stage turbine.

CONSTANT SPEED ADVANTAGE



COMPRESSORS - DIFFUSERS - STATORS - TURBINES
MOST EFFICIENT AT OR NEAR RPM DESIGN POINT

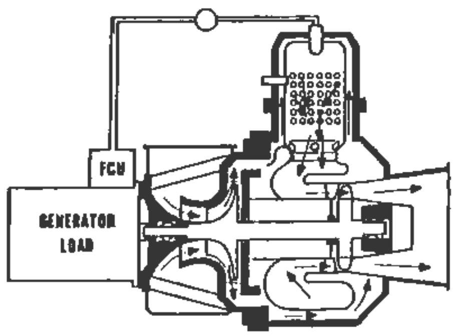
TI-0608-21

#71

The 331 Fixed Shaft Engine is generally known as a "Constant Speed Engine." Though varying speeds can be selected for various purposes, the basic design concept of the engine is operation at a constant speed.

To illustrate that point, the engine could run its entire life at 100% rpm and do it's job beautifully. Compressors, diffusers, stators, turbines, etc., are most efficient when operated at, or near, the rpm design point. Your understanding of the operation of the 331 will be made much simpler if you will remember this concept: the engine basically runs at one speed all the time. The load is varied by changing the blade angle on the propeller, but the engine continues to run at the same speed. This concept is the basis for the power management system to be discussed later.

OTHER CONSTANT SPEED TURBINES



RPM GOVERNING FUEL CONTROL MAINTAINS CONSTANT RPM WITH CHANGING LOADS

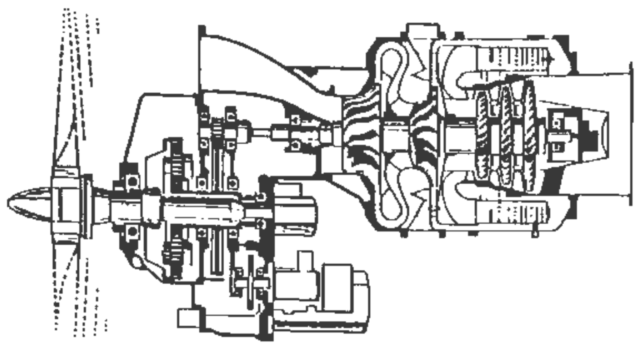
TI-0608-22

#72

To illustrate the basic concept of constant speed we can look at some of the other gas turbine applications. In this illustration, the unit is a small APU, or auxiliary power unit, and it operates on the constant speed principle. The rpm governing fuel control maintains a constant rpm with changing loads. In this case, the load is the generator. As more electrical power is extracted, a greater load is applied to the engine. This increase in load tends to slow down the rotating element of the turbine engine. This reduction in speed is sensed by the speed sensing fuel control, which then gives more fuel to the engine. More power is produced to retain essentially a constant speed as the load changes.

Replace the generator load with a propeller load and consider this concept as we discuss the TPE331.

CONSTANT SPEED ENGINE



TO HOLD SPEED CONSTANT –
TURBINE POWER TO PROP MUST EQUAL LOAD

TT-0608-23

#73

Let's review for a moment the constant speed concept as it applies to the TPE331. This concept is particularly important to understand since it forms the basis for all future discussions relative to both propeller and fuel control systems.

In order to hold speed constant, turbine power to the propeller must equal the load of the propeller. Again, any mention of power still refers to the excess power above and beyond that required to operate the engine's own gas generator. Power produced by the gas generator is relative to the amount of fuel consumed by the engine. Therefore, to hold speed constant, fuel energy to the engine must equal the load of the propeller. The propeller rpm is going to be controlled by a typical propeller governing system. Propeller governing systems are typically oriented to regulate a selected rpm.

Of the two levers used to control this engine, one controls the speed of the engine by regulating propeller rpm and the other controls the fuel energy delivered to the engine. As we examine this drawing, we see that if the engine is running at a constant speed under a given propeller load and the fuel flow is increased, engine rpm also tends to increase. But if the propeller governing system is asking the propeller to regulate its blade angle to a given selected speed, then immediately, the propeller will take on whatever blade angle is necessary to maintain the engine at that speed.

Consequently, as fuel is increased, propeller blade angle will increase and the power or thrust will increase proportionately. However, the engine speed will remain essentially constant.

If the power is reduced by reducing the fuel flow, the tendency will be for the engine speed to decrease. The propeller governor sensing this reduction in rpm will decrease the blade angle so that the engine will be held at essentially the same constant speed. We may better understand now that the instant response of the fixed shaft engine is a tremendous advantage in fixed wing aircraft operation. Assume that during landing, with reduced fuel and a low blade angle at 100% rpm, the aircraft can't use the runway and has to go around and make another approach. Advancing the power lever to increase fuel flow will immediately cause the propeller to respond with an increase in blade angle to hold the rpm at 100%. The response rate to go from idle or no load to full power would be a matter of only the reaction time of the propeller system.

POWER LIMITS

MAXIMUM POWER TAKEN FROM THE TPE331 IS LIMITED BY:

TORQUE (HP) = DETERMINED BY AIRCRAFT DESIGN PERFORMANCE AND STRUCTURAL INTEGRITY

TURBINE TEMPERATURE = DETERMINED BY ENGINE DESIGN

—WHICHEVER LIMIT IS REACHED FIRST—

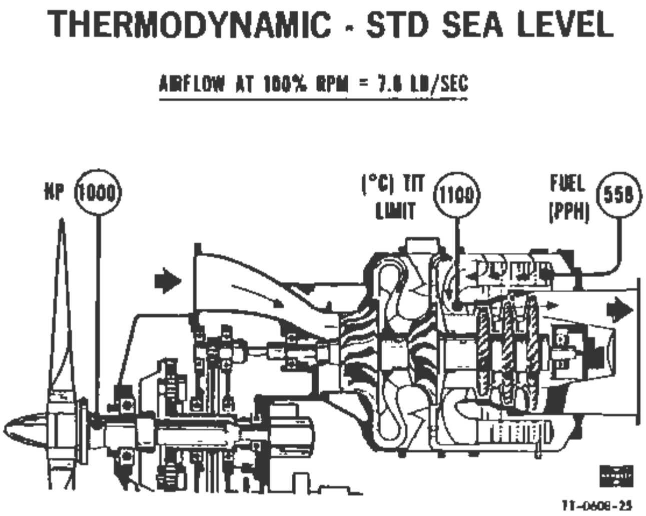
11-0608-74

#74

Standard operating procedure for a typical piston powered aircraft has always been to advance the cockpit throttle lever all the way forward for takeoff power. This is not true with the TPE331 Turboprop. The maximum power that may be taken from the engine is limited by the maximum red lines on either the torquemeter or temperature gage. The maximum torque that can be applied to the aircraft is normally determined by the aircraft design performance and structural integrity. The turbine temperature limit is determined by the engine manufacturer on the basis of the types of materials and the speeds of the critical parts. It is critical to remember that advancement of the power lever for takeoff must stop when either the torque or the temperature limit is reached.

You will see in later discussions that some aircraft utilize an automatic torque or temperature limiting system to prevent the engine from exceeding the temperature or torque limit. However, even on aircraft with such systems, the pilot must always be aware that in the event the torque or temperature limiter is not operating, the ability to stay within these limits is a matter of the pilot monitoring the gages as he applies power.

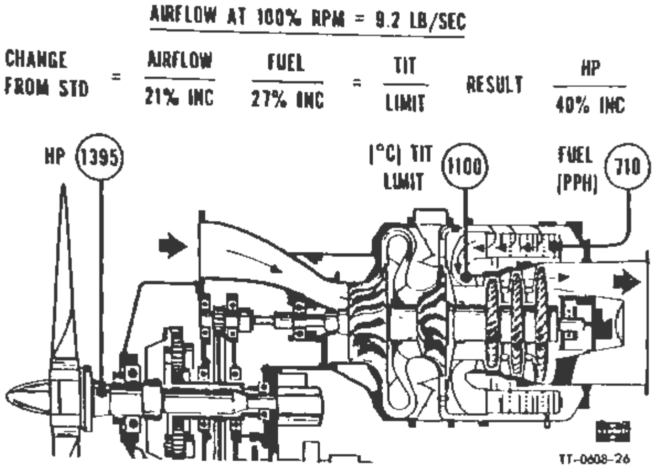
The next series of pictures will illustrate how ambient conditions and ratings of the engine may determine which of these limits is reached first.



#75

You will recall the definition of thermodynamic horsepower rating. To review that definition, the thermodynamic rating of the engine is that power that would be produced at a standard day sea level condition if the engine were run to a maximum turbine inlet temperature. The engine running at 100% rpm under these conditions would pump 7.6 pounds of air per second through the engine. If 558 pounds of fuel were put into that engine, the result would be an 1100° Celsius turbine inlet temperature maximum. Burning that much fuel energy and air mixture would produce under these conditions, 1,000 shaft horsepower. This is the thermodynamic rating of the -10 Engine. The 558 pounds of fuel represents a maximum amount of fuel that could be burned by the engine producing this horsepower and still allow it to meet the required engine specifications. Obviously, an engine with greater efficiency would require less fuel at this temperature to produce this horsepower. The fuel number then, is representative only of a specification limit.

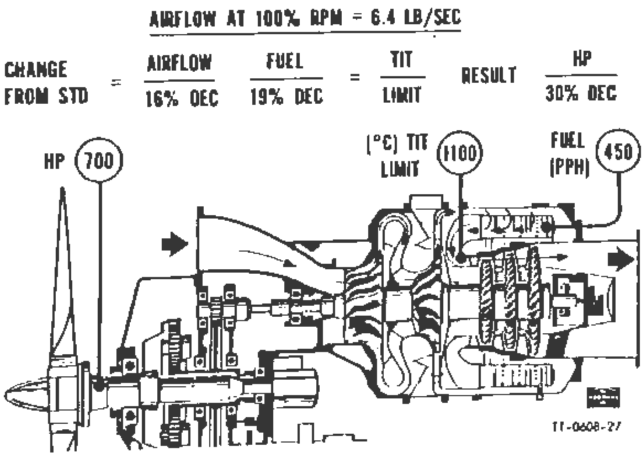
-29°C OAT/SL - EXCEED HP LIMIT



#76

Under these circumstances of cold and dense air, the engine at 100% rpm would pump a through-flow of 9.2 pounds of air per second. Referring to the tabular information on this illustration, this would be an increase of 21% over the airflow pumped by the engine under standard sea level conditions. To run this engine at a maximum turbine inlet temperature of 1100°C would take an increase of 27% in fuel, or 710 pounds per hour. Under these conditions, this engine would produce 1,395 horsepower, which is a 40% increase over its rating. Obviously, this would be an overtorque condition and something could break. This illustration is made to point out that we cannot limit the power only to a turbine temperature. In this case, we would obviously exceed a torque value limit.

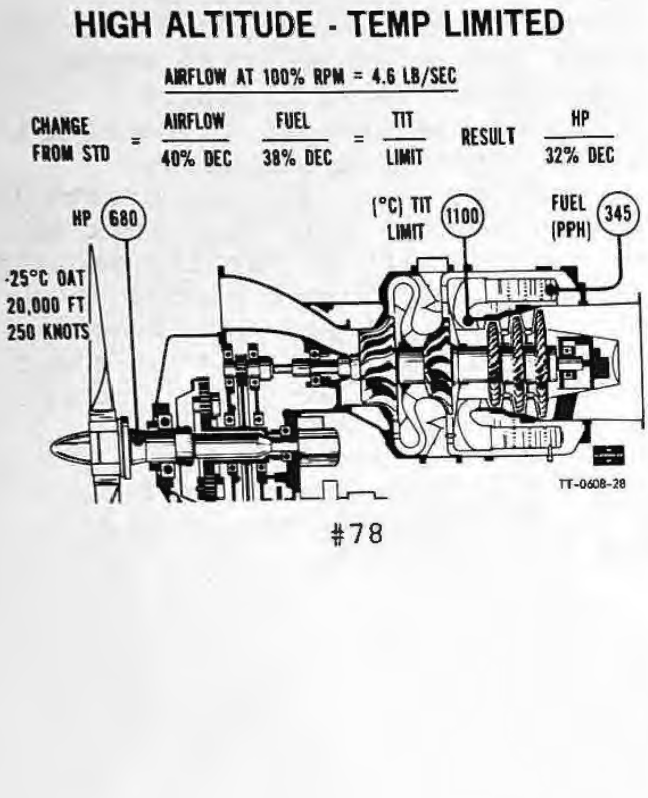
49°C OAT/SL - TEMP LIMITED



#77

It is obvious that at 49°C outside air temperature, the air is less dense. The engine's compressor section rotating at 100% rpm would pump only 6.4 pounds per second airflow. This is 16% less than the engine pumped at a standard sea level temperature and pressure condition. It is easy to see that with less airflow, less fuel is required to reach the 1100° turbine inlet temperature. At the 1100° temperature limit, the engine is burning 19% less fuel with the 16% less air. The result in power is now a dramatic 30% decrease from the standard sea level conditions. 450 pounds of fuel flow was enough to reach the 1100° temperature limit, but only 700 horsepower is being produced.

It is obvious that under this high temperature, low density air condition, any attempt to take the engine to the 1,000 horsepower rating would result in exceeding the turbine inlet temperature limit. The end result would be physical damage to the structural parts of the engine.

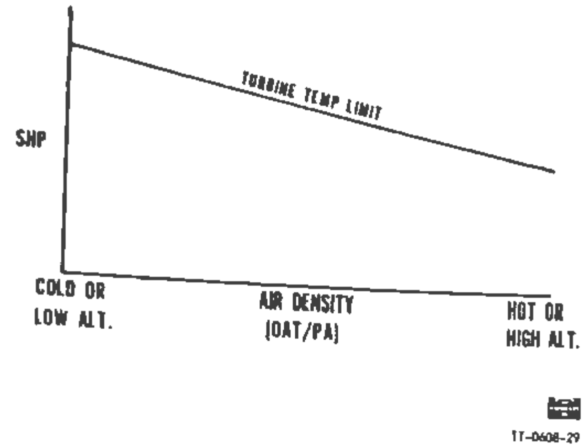


#78

Listed on the left side of this picture are the conditions under which this aircraft is flying. Outside air temperature is 25°C below 0°. Pressure altitude is 20,000 feet and the aircraft is flying at a speed of 250 knots. With the engine at 100% rpm, the compressor would under these conditions pump 4.6 pounds of air per second. This is a 40% decrease from the standard sea level conditions. In order to avoid exceeding TIT limit, fuel flow must be decreased by 38%. With only 4.6 pounds per second of air, 345 pounds of fuel will then be sufficient for the turbine inlet temperature to reach 1100°C. But now only 680 horsepower, a 32% decrease from standard sea level conditions, is being produced.

It can be seen from these last few examples that the TPE331 Engine can be expected to be torque limited at low altitudes and colder temperatures. As the altitude or ambient temperature increases, the engine becomes temperature limited. That's why the power in the 331 Engine is limited to a maximum torque or maximum temperature, whichever comes first.

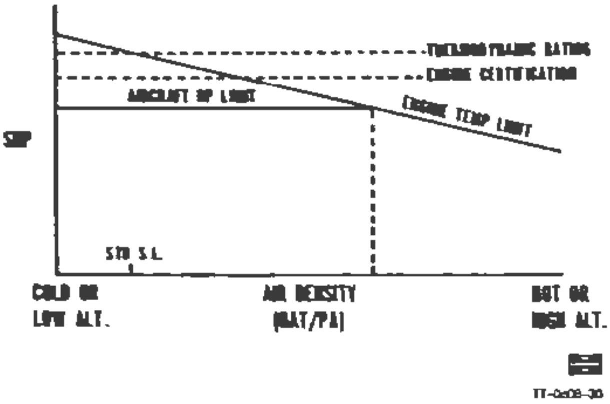
AIR DENSITY vs POWER



#79

If the turbine temperature limit is superimposed across this curve to reflect the horsepower capabilities as a function of air density, we can see that in a cold or low altitude condition, the air is heavy. Greater horsepower can be produced without exceeding turbine temperature. As the altitude or temperature is increased, the air density becomes less. Producing an equal amount of horsepower would require exceeding the turbine temperature limit. This fact should not surprise anyone. All air breathing engines reflect this same lack of power capability as the air density is decreased. To use a common example, most people experience this phenomenon when driving their automobiles into the high country. When the 10,000 feet above sea level point is reached, the automobile just doesn't perform as it did under the sea level, cool air conditions.

FLAT RATE PERFORMANCE



≑80

On this curve, the same engine temperature limit is superimposed on a curve reflecting shaft horsepower capabilities as a function of air density. If a vertical line is drawn from the standard sea level condition, identified at the bottom line, to the top dotted line, the point where it intersects will identify the thermodynamic rating of the engine, which in this case would be 1,000 horsepower. The thermodynamic rating is the engine's capability to produce 1,000 horsepower under sea level conditions at the maximum turbine inlet temperature.

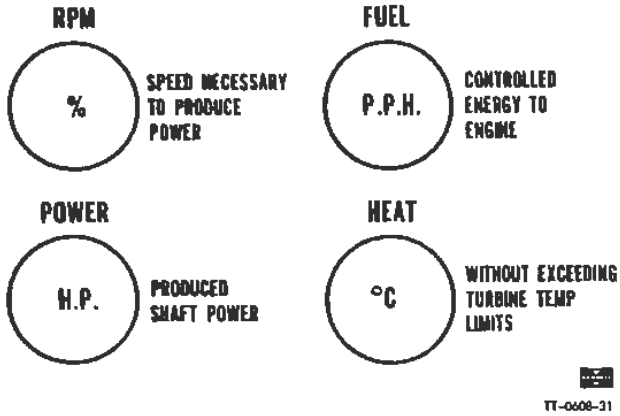
The dotted line below the thermodynamic rating is the point where the engine would be certified by the FAA. Certification could be at performance level, somewhat less than the thermodynamic rating. The particular point at which the engine is certified is determined by a combination of inputs from the aircraft manufacturer. Factors considered are the performance of the aircraft in which the engine is to be mounted and the kind of life and performance expected from the engine. Many aircraft manufacturers will select an engine that has been certified to produce a level of horsepower above and beyond that which is actually needed to make the aircraft perform according to specifications. This is indicated by the third line identified as the aircraft horsepower limit.

As an example, a -10 Engine with a thermodynamic rating of 1,000 horsepower, may be certified to 900 horsepower, yet the aircraft may need only 700 horsepower in order to make it perform. Now what is the advantage of this?

Note the intersect point of the aircraft horsepower limit line and the engine temperature limit line. This engine could provide the 700 horsepower the aircraft needed all the way from a low altitude cold condition up to a much higher altitude or warm air condition before it would become temperature limited. This is a tremendous advantage in performance for the aircraft to be able to utilize that kind of power up to high altitudes. A flat rated engine, thus, increases the altitude performance of the aircraft. It is also easy to see that when the engine has been designed to perform to the thermodynamic rating, has been certified to a level something less than thermodynamic, and then the aircraft manufacturer limits it to something less than certification, the life of the engine will be materially affected. The time between overhauls would reflect a lower cost of operation by essentially working an oversized engine to lower power requirements.

You will recall from the performance ratings discussion earlier in this book that the 331-10 Engine has a thermodynamic rating of 1,000 shaft horsepower. It is certified as a -10 Engine to 900 horsepower up to an ambient condition of 80°F outside air temperature. If this engine is installed in an aircraft that needs only 665 horsepower to make takeoff performance, the margin would be great and it would be able to maintain that 665 horsepower to considerable altitude before reaching the engine temperature limit line.

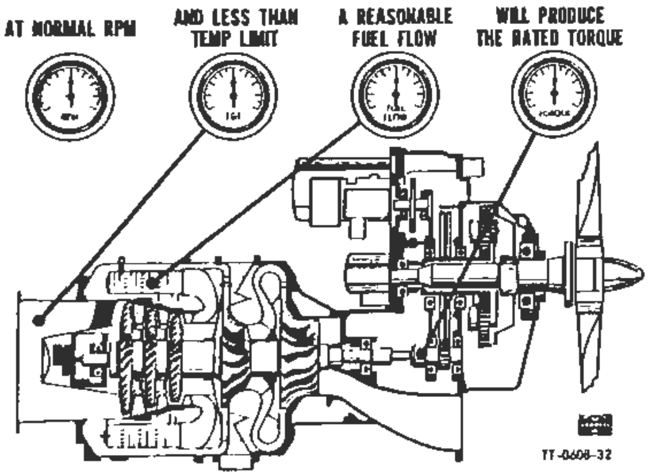
ENGINE PARAMETERS



#81

In a typical aircraft using the TPE331 Engine, each engine will have the four instruments indicated here. The tachometer, or rpm instrument, will indicate the speed in per cent maintained by the engine which is necessary to produce the power. The fuel flow gage will indicate in pounds per hour the amount of energy the operator is putting into the engine. The torquemeter, or horsepower gage, will indicate the shaft power being produced. Units of measurement will vary with aircraft. Horsepower, foot/pounds, and per cent of power, are typical examples. The temperature gage will indicate in degrees Celsius the heat energy leaving the turbine section of the engine. The torquemeter and the turbine temperature gage will have red line limits as previously mentioned.

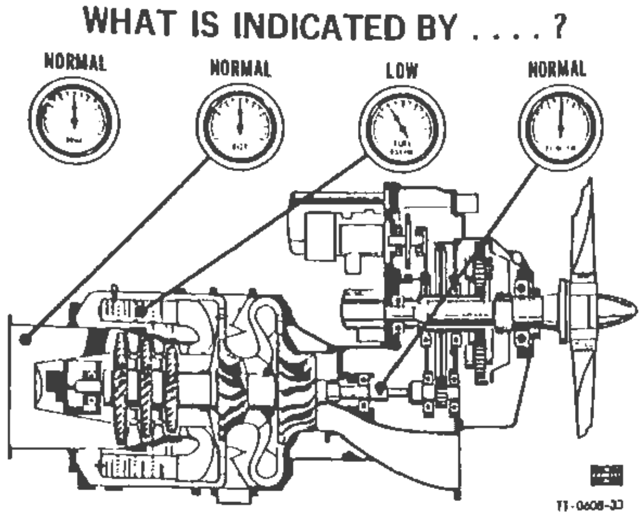
IN A NORMAL ENGINE .....



#82

The maintenance mechanic who recognizes the relationship of these engine instruments under normal operating conditions, is in an excellent position to use these indications as a means of troubleshooting when there is a problem. The definition of normal in this case is that at a normal rpm, and not exceeding the temperature limit, a normal fuel flow should produce the rated torque. Notice that no reference to specific numbers is made at this point. You may be surprised at how much troubleshooting you can do without knowing the specific numbers at this time.

The next series of examples will show you how helpful your knowledge of operational theory of the constant speed turboprop engine will be in troubleshooting from the cockpit.



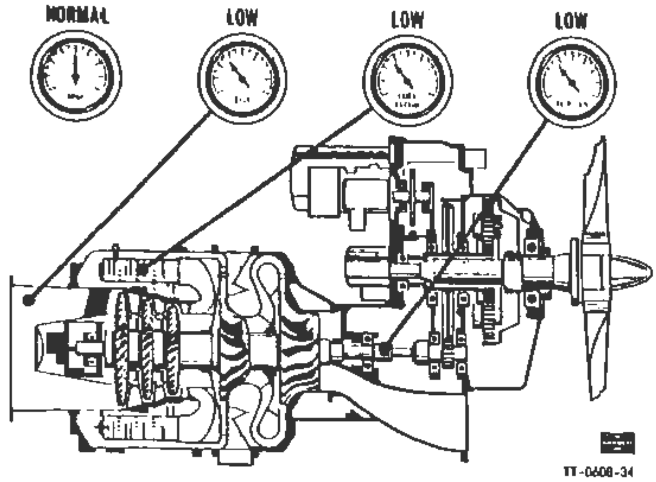
#83

Note that in this example the rpm is normal, the temperature is normal, but the fuel flow is lower than normal. Yet, the torquemeter indicates normal power is being produced. Obviously, internal details of adjustments or component operation cannot be considered, but what do you think is wrong with this particular engine in general?

Let's review the fundamentals. Remember the discussion of the engine as an energy converter? Its function is to take a chemical energy fuel and convert it into useable horsepower. Since this converter is not 100% efficient, some energy will be converted and lost as heat energy. If we look at the instrument ratings we see that the engine is running at its correct speed. The instrument indicates less than normal fuel flow to the engine, yet torque is normal and normal heat energy is going out of the exhaust. Does this sound logical? Obviously, an engine that could produce its rated torque with less than normal fuel, would be desirable, wouldn't it? But it's certainly not logical. There must be the right amount of fuel flow to this engine in order to produce the right torque and the right heat energy. It can be immediately suspected that the fuel flow indication system is malfunctioning. In reality, there must be a normal amount of fuel into the engine to produce the normal torque and normal temperature.

This seems to be an oversimplified procedure and, in some respects, may be. However, all too often fuel controls are replaced and other components are changed without the mechanic realizing that it is impossible that the fuel control could be the cause of this problem.

WHAT IS INDICATED BY . . . . ?

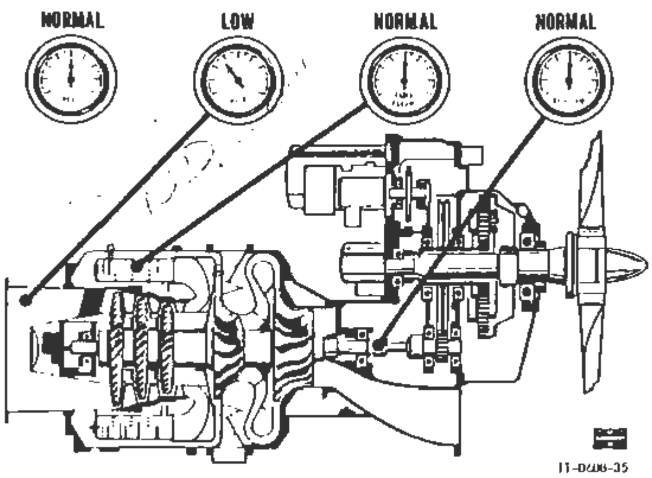


#84

Let's examine another set of circumstances. In trying to make takeoff power, rpm is normal, yet the temperature is too low, fuel flow is too low and the torque is too low. Think again of the energy conversion concept.

It is apparent that if the fuel flow is too low, obviously, the engine cannot produce the normal torque or temperature it should. The fact that all three indications are low would indicate only that the engine is fuel limited. It is unimportant at this point to attempt to determine the detailed problem within the fuel system, but getting these gage indications and analyzing this set of circumstances can be valuable in determining that the problem is in the fuel system and not in the propeller governing system, torque indication system or in other devices. The next step would be to troubleshoot the fuel system.

WHAT IS INDICATED BY . . . . ?



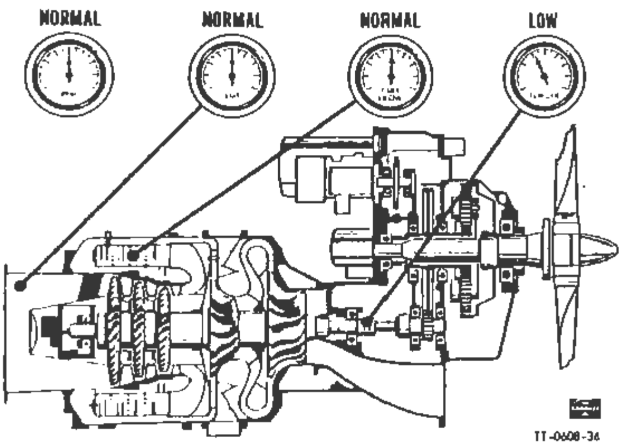
#85

Under this set of circumstances, the rpm is normal, the temperature is lower than normal, the fuel flow is also normal, and the engine is producing the right amount of torque. Consider these indications for a moment and determine what the basic problem is.

It's apparent that the temperature, fuel flow, and torque indications are very closely related. It is obvious that these indications, where fuel flow and torque are both normal and the temperature is abnormal, do not follow theory of operation of energy conversion. If the right amount of fuel is put into the engine and the right amount of torque is produced, the engine must then be producing the right amount of temperature.

If the indicator does not agree, then the indicator is at fault. Though it is conceivable that both the fuel flow and the torquemeter indicator systems might be malfunctioning and that the engine is really running at a fuel limited condition, the possibility is very remote. The fact that fuel flow and torque are both normal indicates that the engine is doing its job in converting the right amount of fuel into the right amount of torque and consequently must be putting the right amount of heat energy out the exhaust. In this case, the malfunction is most likely the temperature indication system.

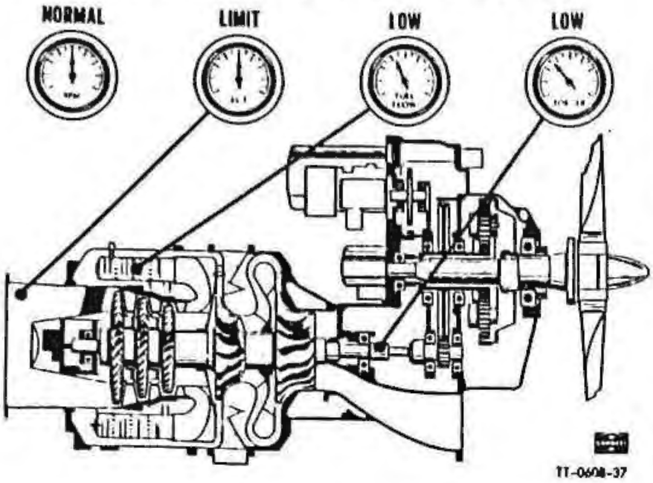
WHAT IS INDICATED BY . . . . ?



#86

In this instance, the rpm is normal, the temperature is normal, the fuel flow is normal, but the torquemeter reads below normal. Using the same thought process as you did in the previous examples, you should come to the conclusion that the torquemeter is reading improperly. Again, if the fuel flow is what it should be and the heat energy is what it should be, then obviously the power being produced to the propeller is normal and the torquemeter has a malfunction in its indication system.

WHAT IS INDICATED BY . . . . ?



#87

Now that you have had a chance to become proficient in analyzing the engine instruments, let's look at these final circumstances. In an attempt to make takeoff power, the engine is at the correct rpm and has reached the temperature limit, yet the fuel flow is slightly low and the torque is considerably low. Can you determine what the problem is?

The conclusion should be that the temperature indicating system has a malfunction that causes it to read too high. Let's analyze that. Assuming that an error in the temperature indicating system is causing the indicator to read higher than it should, it is conceivable that as the power lever is advanced to put more fuel into the engine to produce takeoff power, the gage would reach a point where it indicates that the temperature limit has been reached. In accordance with instructions, the lever will not be advanced beyond that point. Then, if the gage is reading higher than it should, further increase in fuel into the engine has been stopped at a point less than normal. Consequently, the power being produced will be less than normal. So if you determined that the possibility of a temperature indicating system reading too high was the problem, you are correct. But wait a minute!! Is there anything else that would give this set of indications?

Consider for a moment the power conversion principle. The fuel energy into the engine is converted either into torque or heat energy out of the exhaust.

If the efficiency of that engine has been reduced, then a greater share of that fuel energy would go out the tailpipe to be recorded as heat energy rather than converted into useable horsepower. This means that at some point less than normal fuel flow, that energy has reached the temperature limit. These conditions of less efficient power conversion could also be as indicated on the instruments. This particular case could indicate the relatively simple problem of the temperature indicating system needing attention, or it could also indicate a deterioration in the performance of the engine as an energy converter. It is important for the engine maintenance mechanic to have additional troubleshooting tools at his disposal. The decision to fix the temperature indicating system or to remove the engine and send it to the major repair facility represents a substantial dollar difference.

Later on in the book there will be additional cockpit troubleshooting to show the mechanic that a decision can be made readily without even leaving the cockpit. This series of cockpit instrument indication analysis is intended to show the troubleshooting mechanic that he should not overlook the obvious. An indication of the cockpit instrumentation can many times reduce the time and dollars spent in solving the problems that may occur with the engine. These exercises emphasize the importance of the basic concept of energy conversion and a recognition that these engine instrument indications are related to each other.

SUBJECT:
SECTION 3 - THEORY OF OPERATION

WORKBOOK EXERCISE 2

1. The main rotating group of the TPE331 engine consists of:

   a. A three-stage axial compressor section and a two-stage radial turbine section.
   b. A two-stage centrifugal (radial) impeller compressor section and a three-stage axial turbine section.
   c. A three-stage centrifugal (radial) compressor section and a two-stage axial turbine section.

2. The device that converts mechanical energy into pneumatic energy is called:

   a. A turbine.
   b. A combustor.
   c. A gearbox.
   d. A compressor.

3. The gear section of the engine converts high rpm-low torque to low rpm-high torque.

   a. True.
   b. False.

4. Correct operating technique would allow advancing the power lever until:

   a. The turbine temperature limit is reached.
   b. The aircraft torque limit is reached.
   c. Either "a" or "b," whichever occurs first.

5. Labyrinth seals prevent air leakage between stages within the engine during operation.

   a. True.
   b. False.

6. Airflow through the compressor diffuser divergent duct:

   a. Remains at constant velocity and decreases static pressure.
   b. Decreases velocity and increases static pressure.
   c. Increases velocity and static pressure.

WORKBOOK EXERCISE 2

7. The pressure and temperature of the air, as it passes through the two-stage compressor section, will:

   a. Increase.
   b. Decrease.
   c. Pressure will rise, but temperature will remain the same.
   d. Temperature will rise, but pressure will remain the same.

8. The pressure ratio across a compressor section, when operating at a standard sea level ambient and producing a P_3 pressure of 135 psig, would be:

   a. .098:1
   b. 10.2:1
   c. 9.2:1
   d. .109:1

9. The air pressure at Station Three would be:

   a. Less than Station 2.1.
   b. Less than Station 4.
   c. Less than ambient, but at a greatly increased velocity.
   d. The point of highest air pressure within the engine.

10. The velocity of the gases at Station Four would be:

    a. Less than at Station 3.
    b. Greater than at Station 3.
    c. Equal to that at Station 3.

11. The air flow through a stator nozzle in the turbine section:

    a. Remains at a constant velocity, but changes pressure.
    b. Decreases in velocity.
    c. Increases in velocity.

12. The temperature and pressure of gases as they pass through the three-stage turbine section will:

    a. Decrease.
    b. Increase.
    c. Remain unchanged.

WORKBOOK EXERCISE 2

When studying the operation of the TPE331, it is important to remember that if engine speed (rpm) is to remain constant, power to the propeller and propeller load must be equal. The following questions are directed toward this load/power/rpm relationship.

13. If propeller load remains constant and power is increased, what will happen to rpm?

    a. The rpm will decrease.
    b. The rpm will increase.
    c. The rpm will not change.

14. If power is increased, what must happen to propeller load if rpm is to remain constant?

    a. Propeller load must decrease.
    b. Propeller load must increase.
    c. Propeller load must not change.

15. If power remains constant and propeller load is increased, what will happen to rpm?

    a. The rpm will decrease.
    b. The rpm will increase.
    c. The rpm will not change.

16. If propeller load remains constant, and power is decreased, what will happen to rpm?

    a. The rpm will decrease.
    b. The rpm will increase.
    c. The rpm will not change.

17. If propeller load is increased, what must happen to power if rpm is to remain constant?

    a. Power must decrease.
    b. Power must increase.
    c. Power must not change.

18. If propeller load is decreased, what must happen to power if rpm is to remain constant?

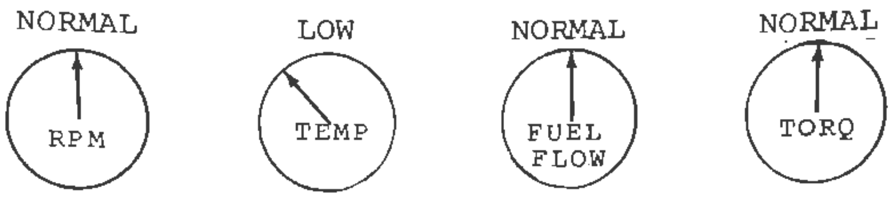
    a. Power must decrease.
    b. Power must increase.
    c. Power must not change.

WORKBOOK EXERCISE 2

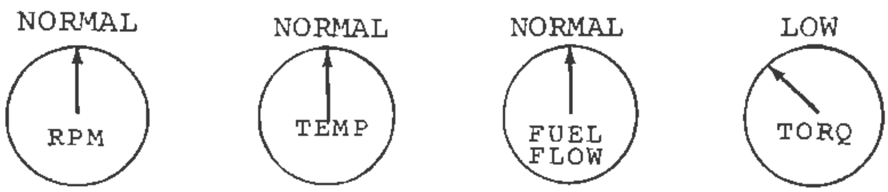
The following questions are an exercise in cockpit troubleshooting using the engine parameters as displayed on the cockpit indicators. Select from the following list, the answer that describes the problem area.

a. Fuel flow indication system problem.
b. Temperature indication system problem.
c. Torque indication system problem.
d. Low engine efficiency.

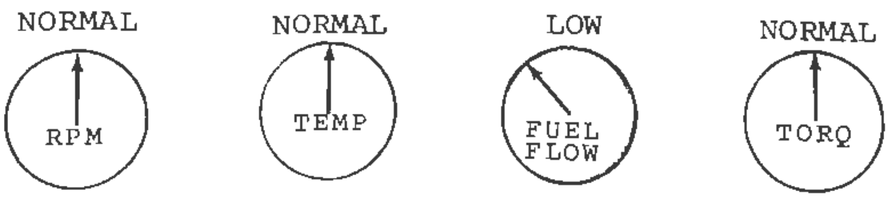
ANSWER

19. 

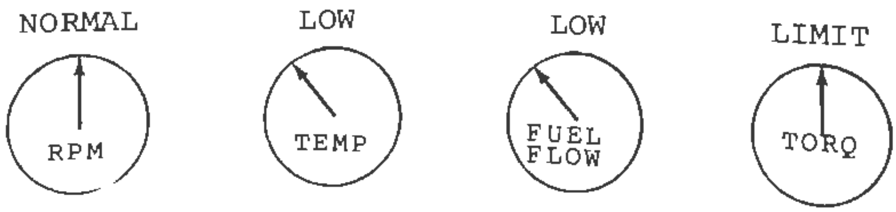
______

20. 

______

21. 

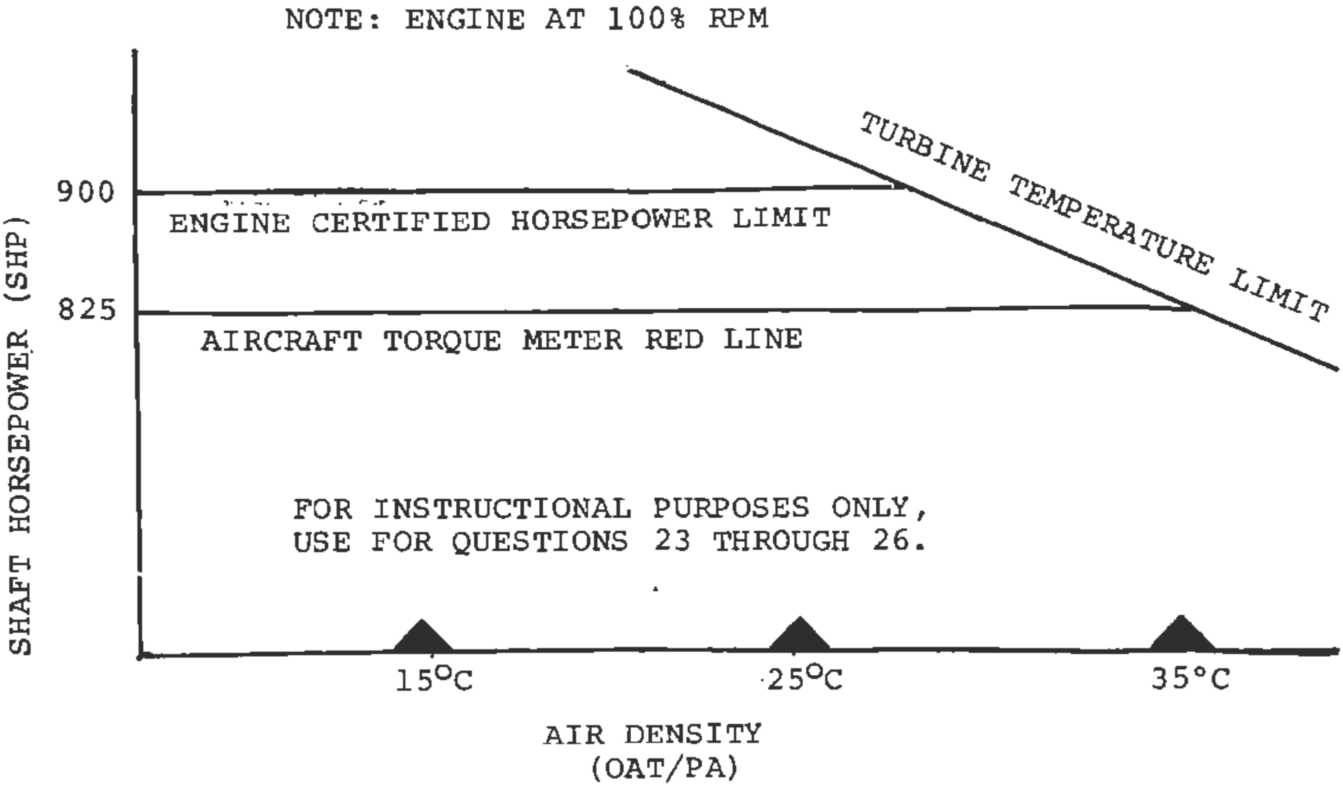
______

22. 

______

WORKBOOK EXERCISE 2

The following chart and associated questions will relate the effect of changes in ambient temperature and pressure altitude on engine performance. The aircraft in question is equipped with -10 engines, flat rated to 825 shaft horsepower at 100% rpm on a 35°C standard sea level pressure altitude day.



23. Assuming a sea level pressure altitude with an ambient temperature of 25°C, will takeoff power be limited by torque or turbine temperature?

    a. Torque limit.
    b. Turbine temperature limit.
    c. Both limits will be reached at the same time.
    d. Neither limit can be reached.

WORKBOOK EXERCISE 2

24. After takeoff, with the conditions set forth in question 23, a given torque value was maintained while climbing to altitude. What effect would this have on turbine temperature?

    a. Turbine temperature will decrease as altitude increases.
    b. Turbine temperature will not change unless the pilot makes a change in fuel flow.
    c. Turbine temperature will increase as altitude increases.

25. At the time of departure from the second airport, ambient temperature is 45°C with a pressure altitude higher than sea level standard. To establish takeoff power, the pilot should advance the power lever:

    a. To torquemeter red line and note the turbine temperature reading.
    b. To turbine temperature limit and note the torquemeter reading.

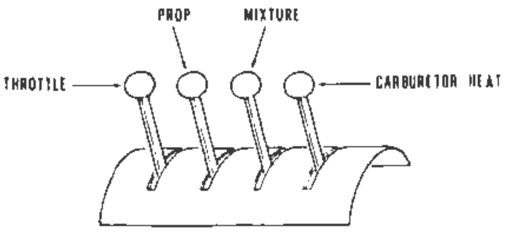
26. The pilot of the aircraft described prior to question 23 decided to demand 900 SHP for takeoff on a standard sea level ambient day. His actions may result in:

    a. Damage to the aircraft by exceeding the aircraft manufacturer's torque limit recommendations.
    b. Damage to the engine turbine section by exceeding temperature limits.
    c. Damage to the gearbox section of the engine by exceeding engine torque limits.
    d. None of the above. It's all right under any condition to take the maximum power the engine is certified to produce.

SECTION FOUR:

OPERATIONAL SEQUENCE

PISTON ENGINE CONTROLS



FOUR CONTROLS PER ENGINE

IT-0609-3

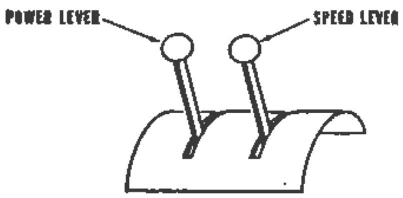
#91

This picture reminds us of the four typical controls found in reciprocating engine cockpit quadrants.

First, there is a throttle used to control fuel. Next is a propeller control used to adjust the propeller governor. Thirdly, a mixture control is used to vary the mixture of air and fuel to the carburetor. Finally, a carburetor heat lever prevents icing of the carburetor during power letdown or when flying in known carburetor icing conditions.

It can readily be seen that four controls per engine results in a very busy quadrant.

TPE331 COCKPIT CONTROLS



TWO CONTROLS PER ENGINE

IT-0609-4

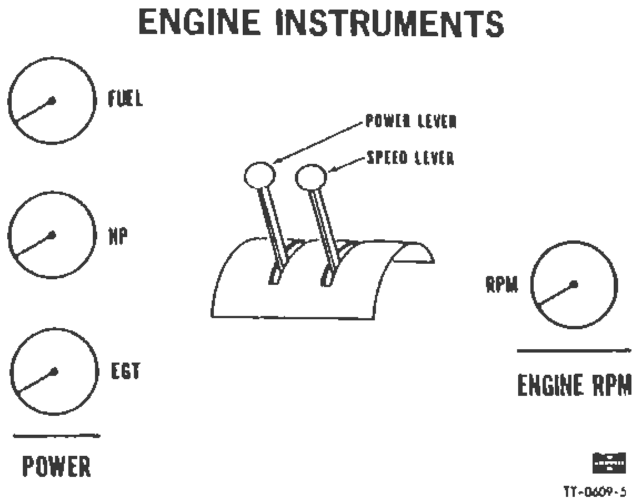
#92

On TPE331 Powered Aircraft, the cockpit quadrant contains only two engine controls--the "Power Lever" and the "Speed Lever."

The power lever--which is to the left in this drawing--relates to the throttle in reciprocating engines. But this lever does more than control fuel. The power lever also gives the pilot control over propeller thrust during ground operation.

The speed lever--sometimes called "Condition" lever--is shown to the right in this picture. It primarily controls the selection of engine rpm the pilot desires.

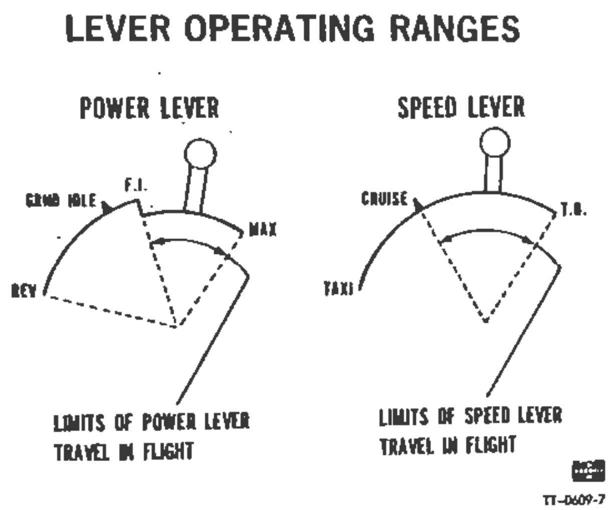
In those aircraft applications in which the speed lever is referred to as a "Condition Lever," it acts as an emergency shutoff lever, as well as, a speed control. To maintain consistency, we will use the term "Speed Lever" throughout this book.



#93

As can be seen in this illustration, the engine instruments on the left--representing fuel, horsepower and exhaust gas temperature--are related to the power being produced by the engine, or the power lever.

The speed lever, on the other hand, is essentially responsible for selecting rpm, as indicated on the engine tachometer.



#95

These two drawings indicate the power and speed lever positions as identified on the cockpit quadrant.

Starting with the left side drawing of the power lever positions, we see there are four. The full back position--the position in which the lever is pulled closest toward the pilot--is identified as "Reverse." Going forward, the next position labeled is "Ground Idle." Forward of ground idle is the "Flight Idle" position. The full forward position--in the direction farthest away from the pilot--is usually called "Maximum."

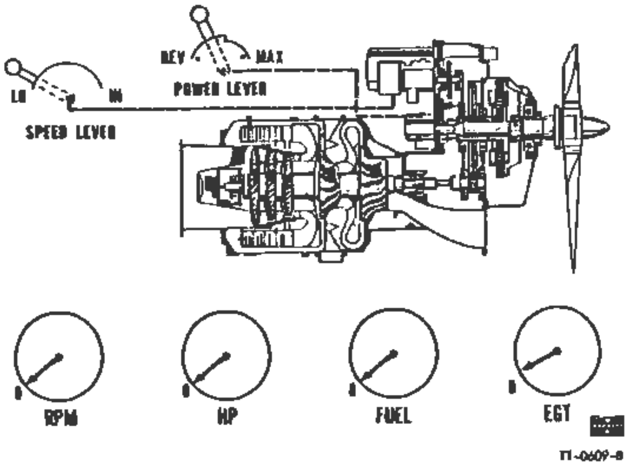
As seen by looking at the arrows, power lever travel in normal flight operation is from flight idle to maximum. The aircraft must be on the ground before the pilot can bring the power lever farther back than the flight idle position. It is for this reason that the flight idle position is a "hard stop."

It contains a detent and the pilot must make a specific effort to move the power lever out of flight idle into ground idle or reverse.

The speed lever markings are illustrated on the right side picture. The full back position is identified as "Taxi." The next position forward is a detent marked "Cruise," which is the minimum cruise rpm speed. The full forward position is labeled "Takeoff," or in some aircraft, "Takeoff and Landing." The dotted lines and arrows reflect the total speed lever travel in flight between the takeoff and cruise positions. The aircraft should be on the ground before the pilot brings the speed lever back to the taxi position.

With the information we have at this point, we will now go through a complete cycle of engine operation to discover what happens in the positioning of these levers.

PRESTART



#96

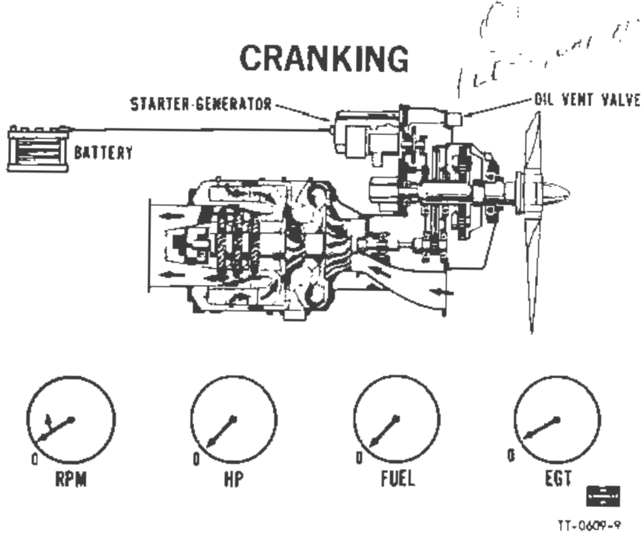
Several items should be checked before starting the TPE331 Engine. In addition to the oil level, fuel supply, and area around the propeller, the inlet and exhaust ducts must be checked for obstructions. Also, the propeller must be at a flat pitch position prior to starting, in order to reduce the load that the starter has to overcome during cranking. This flat pitch position of the propeller prior to starting is referred to as the propeller being "On The Locks."

Lock pins are located in the hub area of the propeller. Their function is to prevent the feather springs from driving the propeller to the feathered position.

If the propeller were in a feathered position, it would create an overload that would resist cranking. Another area that needs preflight attention is the battery. There must be adequate cranking power to start the engine. The proper auxiliary power unit can also be used to ensure an adequate supply of 24 volt power.

Looking at the illustration labeled "Prestart," we see the position of the engine control levers in preparation for a start. The power lever is placed at, or near, flight idle so that the propeller is on the start locks. The speed lever is placed in the low rpm, or taxi position.

Notice also the gage readings across the bottom of this illustration. All are at zero except for the temperature gage. It should read approximately ambient temperature.



#97

As the engine start switch is moved to the "On" position, the aircraft relays will be pulled in to supply a source of 24 volts to the starter generator. This 24 volts will also be applied to the oil vent valve, which is visible in the upper right hand corner of this drawing.

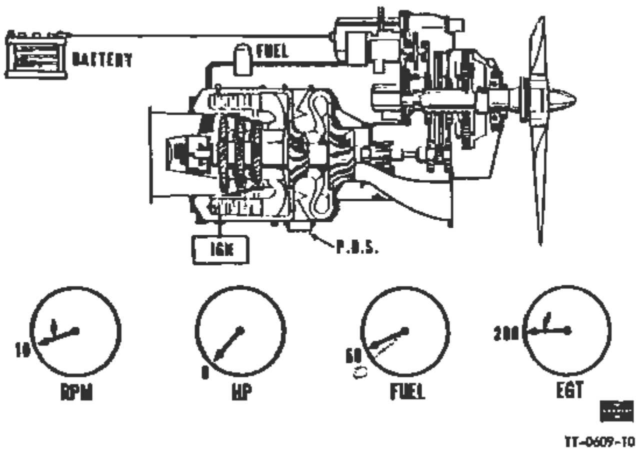
The purpose of the oil vent valve is to relieve the load created by the oil pumps during all starting conditions.

As the engine starts to rotate, the rpm gage will start to show a slight upward rise from zero. There are no noticeable changes in the other indicators at this time. It is important at this point in the operating cycle that no fuel be introduced into the engine. Fuel in the engine during cranking could result in a flaming start.

This is prevented by the purging action of the compressors, which draw in outside air, compress it, and force it through the turbines and exhaust.

Fuel is not introduced into the engine until the ten per cent switch is activated.

LIGHTOFF AT 10% RPM



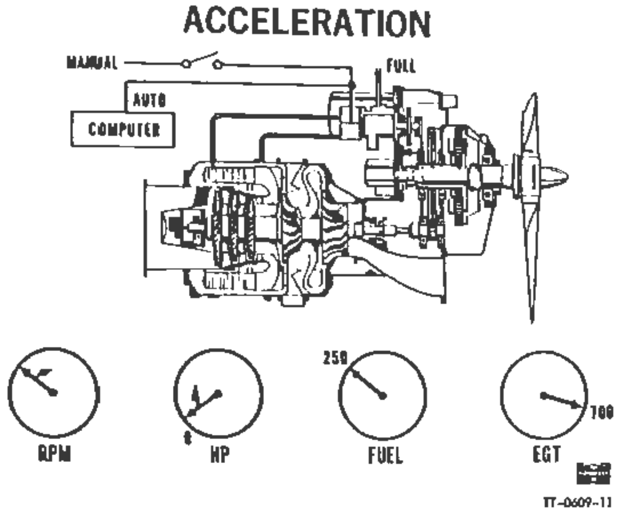
#98

By the time the engine reaches ten per cent rpm, there is sufficient airflow through the power section to sustain combustion. The engine start control system will receive a signal indicating the engine speed. When this ten per cent signal is received, the control system will accomplish several tasks. The system will open the fuel shutoff valve to allow fuel to be introduced into the combustion section. It will also actuate the ignition system, causing the ignitors to give off the spark that will light the fuel. This is commonly called "Lightoff." The ten per cent signal also energizes the "Primaries Only Solenoid" open. We will see later--in the fuel system discussion--the purpose of this solenoid.

Shortly after passing ten per cent rpm, a sudden increase will register on the fuel flow indicator. Accompanying this increase in fuel flow will be a rapid rise in temperature.

This indicates that lightoff has been accomplished. From this point on, the temperature indicator will be the important gage to watch. Maximum temperature limits must not be exceeded. Rpm must also be monitored for a smooth rate of acceleration.

If the sudden increase in fuel flow and temperature does not occur, the start should be aborted, and corrective action taken.



#99

Besides activating the fuel shutoff valve and ignition system, the engine speed signal to the auto start computer also energizes an automatic fuel enrichment system. This system will normally supply whatever fuel is necessary to maintain an acceptable rate of acceleration without exceeding a preset safe temperature limit. This enrichment system may be manually overridden if necessary.

The instrument indications that would appear at this point in the operational cycle are shown along the bottom of this picture. The rpm will now be increasing without hesitation.

The torquemeter will start to indicate a slight increase. The fuel flow indication may typically go up to about 250 pounds per hour. Temperature may be near 700° Celsius. Do not exceed the maximum EGT of 770° for one second. During this period of operation, the pilot really has nothing more to do than monitor these gages. Acceleration is completely automatic as a result of a P3 air signal received by the fuel control.

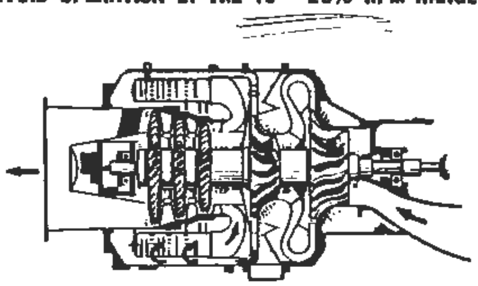
As the engine increases in speed, compressor discharge--(P3)--air pressure increases. This pressure increase causes a signal to be sent to the fuel control for additional fuel. The more fuel energy put into the engine, the higher the turbine temperature will be.

Consequently, greater power is extracted resulting in greater speed of the compressors. The increase in compressor speed causes an increase in P3 and the whole cycle repeats itself.

The pilot needs only to monitor the instruments, noting any abnormality that would cause him to abort the start cycle. These are primarily, high temperature, or a slow rate of acceleration that may delay the acceleration through a critical frequency rpm range.

CRITICAL SPEED RANGE

AVOID OPERATION IN THE 18 - 28% RPM RANGE



TT-0609-12

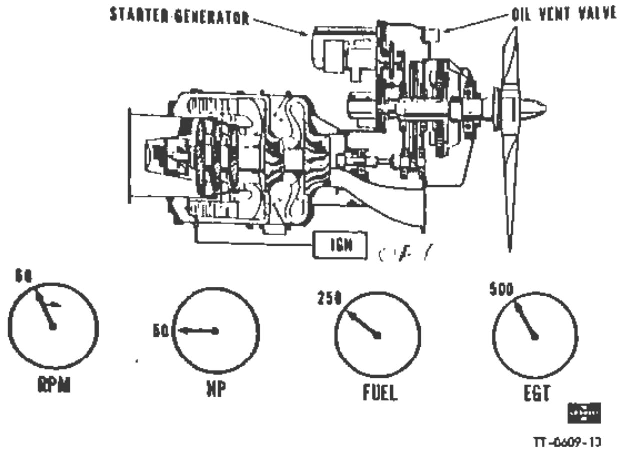
#100

The critical speed range of the TPE331 Engine is in the 18 to 28 per cent rpm range. Prolonged operation in this speed range should be avoided. As the engine accelerates, it should increase in speed smoothly through this range.

This picture illustrates the consequences of keeping the TPE331 Engine in the 18 to 28 per cent rpm range. The rotating group will begin to vibrate and eventual physical deformation of the parts or metal to metal contact could result.

It is important to remember that the critical speed range is below the normal operating speed range. It is of prime concern only during the start sequence that we maintain a good rate of acceleration through the critical range. If the increasing rpm appears to hang in this range, the engine stop switch should be activated, thus aborting the engine start.

60% RPM

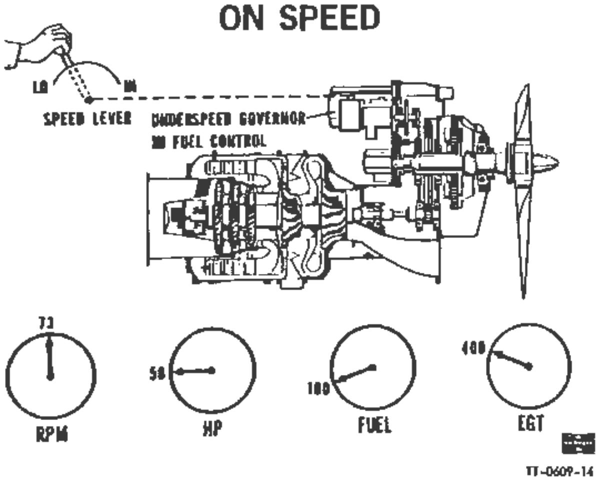


#101

As the auto start computer senses that the engine has reached the 60 per cent rpm point, relay action within the aircraft system de-energizes the starter generator, and at 60 per cent, the engine is self-sustaining. The oil vent valve will also be closed, and the ignition system de-energized, since the fire for combustion has been established.

Note the cockpit gage readings shown in this picture. The rpm is increasing above the 60 per cent rpm point. The torquemeter reading is also increasing. Fuel flow is still in the 250 pound range at this point in acceleration. The temperature, however, is starting to decrease because of the greater supply of air to the engine caused by the increasing speed.

ON SPEED



#102

Up to this point, the engine has been accelerating because of a P3 air signal to the fuel control requesting additional fuel. Since the fuel energy going into the engine exceeds the amount necessary to carry the load of the propeller on the start locks, the rpm increases.

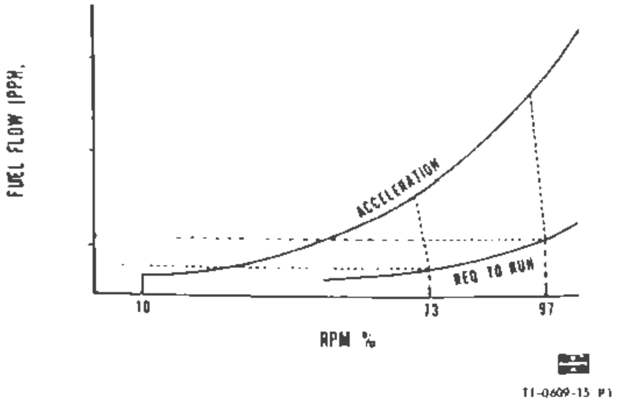
Remember, when the engine was started, the propeller was on the start locks at a very low pitch blade angle.

When the speed lever was placed in the low rpm or taxi position, a connection from the speed lever to the fuel control adjusted the spring value on a governor. This governor is called the "Underspeed Governor."

The adjustment of the underspeed governor spring represents an rpm of approximately 65 to 75 per cent, depending on the aircraft installation. (The speed lever positions the underspeed governor in the fuel control to stop the acceleration when rpm reaches this adjustment point.) As the engine speed approaches this point, the governor will begin to reduce the fuel so that it will ultimately provide the necessary amount of fuel to carry the propeller load at the rpm that the operator has requested. This condition is called the "On Speed" condition and is illustrated in this picture.

Note the cockpit instrument indications. The rpm has stopped at 73 per cent. The torquemeter still reads low since the propeller is on the locks and not much load can be produced. Fuel has been reduced by the action of the underspeed governor and will stop at about 100 pounds per hour. EGT has dropped because fuel has been reduced.

REQUIRED FUEL



#103

In this curve, fuel flow in pounds/per hour and engine speed in per cent of rpm are compared.

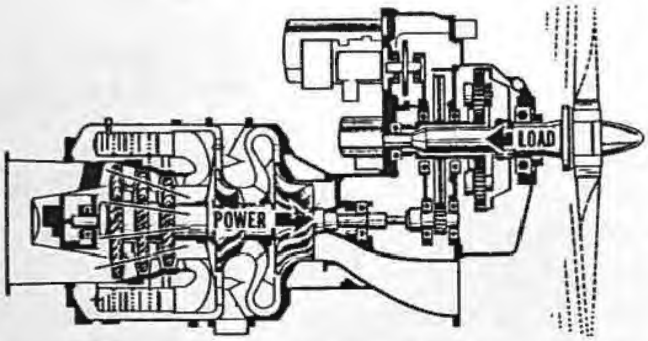
If you look at the acceleration line, you see that fuel starts to flow at about ten per cent rpm. As we follow the acceleration line, we see the effect of increasing P3 air. The P3 air signal to the fuel control causes a sufficient quantity of fuel to be added to make the engine accelerate. Notice as we approach the 73 per cent rpm point, the dotted line, representing fuel, drops and intersects a line identified as "Required To Run." This drop reflects the action of the underspeed governor.

As the governor senses the approach to 73 per cent rpm, it starts to meter the fuel. The underspeed governor restricts fuel to only that quantity necessary to carry the load of the engine at 73 per cent. As we have already discovered, this took approximately 100 pounds per hour.

The dotted line that we have followed is a function of the speed lever being set at the lower rpm position. If the engine were started inadvertently, with the speed lever at the high rpm position the underspeed governor would be calibrated to 97 per cent and the engine would continue to accelerate at the fuel flow indicated by the acceleration curve. Eventually the underspeed governor would sense the approach to the 97 per cent rpm point and the amount of fuel would be reduced to only that amount necessary to carry the load of the propeller on the locks at 97 per cent rpm, which, in this case, would be about 200 pounds of fuel.

Starting the engine with the speed lever at the high rpm position would not be detrimental to the engine. The idea of starting at low rpm is recommended because the noise of the propeller is reduced during the start and ground operation.

CONSTANT SPEED



TO HOLD SPEED CONSTANT, EXCESS TURBINE POWER MUST EQUAL PROPELLER LOAD

TT-0609-16

#104

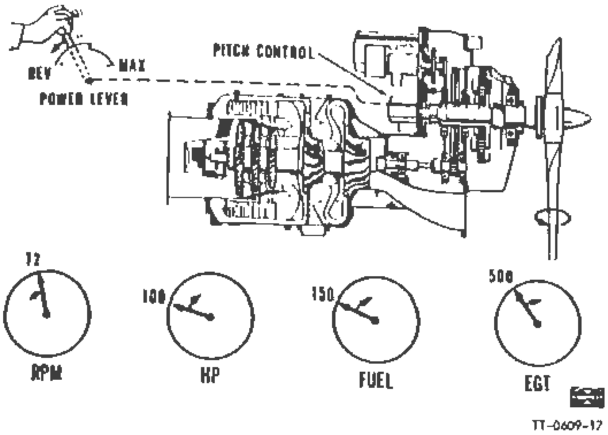
This picture reminds us again of the basic constant speed principle.

You will recall that in the Theory of Operation section of this book, we described the balance of power and load at any given rpm. In that discussion, we referred to 100 per cent speed only. However, this principle holds true at any speed.

In the case of starting, we have selected 73 per cent rpm as the speed we wish to run the engine. That's why the fuel control reduced the fuel to only the amount necessary to carry the load of the propeller at 73 per cent rpm.

The selection of points between the 73 per cent and 97 per cent rpm values is actually unlimited. The speed lever could be placed at any position between the low and the high speed point and the governor would regulate the fuel to maintain that speed. The low speed position is normally selected to keep the propeller noise down.

PROP LOCKS RELEASED



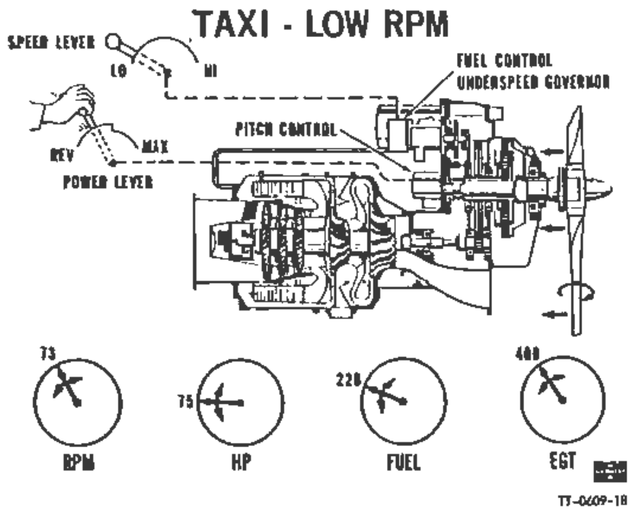
#105

When the engine has accelerated to an "On Speed" condition, more power is needed to produce thrust. Obviously, obtaining this thrust would be difficult with the propeller held at a fixed low pitch blade angle. In order to take the propeller off the locks, it is necessary for the pilot to move the power lever toward the reverse position. As he does this, he changes a pitch control position causing oil to flow into the propeller which moves it toward a reverse blade angle. This allows the start locks to retract. The propeller blade angles are now moveable to any position the pilot demands.

Notice that the rpm has dropped from 73 per cent to 72 per cent. This reflects the load that the pilot is putting on the engine, which causes a slight reduction in rpm. In response to this reduction, the fuel flow increases slightly as a result of the underspeed governor's effort to keep the engine running at 73 per cent. Increase in fuel causes an increase in temperature and, of course, horsepower goes up slightly as a function of the load placed on the engine. It can be seen at this point, that the pilot is controlling propeller blade angle by the position of the power lever. Notice that the power lever is positioned behind the flight idle hard stop. Under these conditions, a blade angle all the way from some degree of reverse to a positive blade angle can be selected through the action of the pitch control.

Since the propeller is being controlled by the power lever, the speed lever is controlling the speed of the engine. The speed is being maintained at approximately 73 per cent by the action of the fuel control underspeed governor.

Under ground operation conditions, it becomes evident why the power lever is not called a "Throttle." This is truly a single power lever control system, not just a throttle.



#106

Even though the TPE331 Engine is a constant speed engine and is designed to operate at or near 100 per cent rpm for maximum efficiency, it becomes evident that in a fixed shaft engine, the propeller would make considerable noise turning at 100 per cent rpm, even with low pitch. It is for this reason that the speed is adjusted down as low as 65 to 75 per cent.

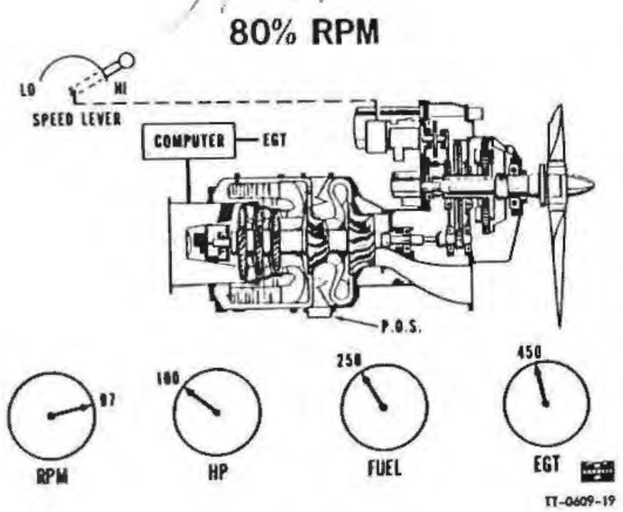
Notice that in this illustration, the speed lever remains in the low or taxi rpm position. If the pilot wishes to taxi the aircraft, he moves the power lever forward for forward thrust, or aft for reverse thrust. The ground idle position is the zero thrust position in which the blade is at the flattest pitch it can be.

As the pilot moves from ground idle back towards reverse, he can literally back up the aircraft or he can use reverse to brake the aircraft's forward motion. When the pilot advances the power lever forward of ground idle, the blade will assume a positive pitch angle and create the thrust that moves the aircraft in a forward direction. Notice the instrument indications. The rpm is staying close to the 73 per cent reading.

The only reason for torque, fuel flow, and EGT to vary is as a reflection of changing load conditions as various blade angles are selected.

Under these conditions, with a quiet propeller, the pilot can taxi out to the takeoff area. Should the aircraft be heavily loaded, or the ramp areas have an uphill grade, the pilot should be aware of the tendency to overload the engine at a low speed. He can advance the speed lever to whatever rpm is necessary between the 73 and 97 per cent range, to carry whatever load is necessary.

The pilot does not have to taxi at low rpm. He could select 80 per cent, or even 97 per cent, if necessary.



#107

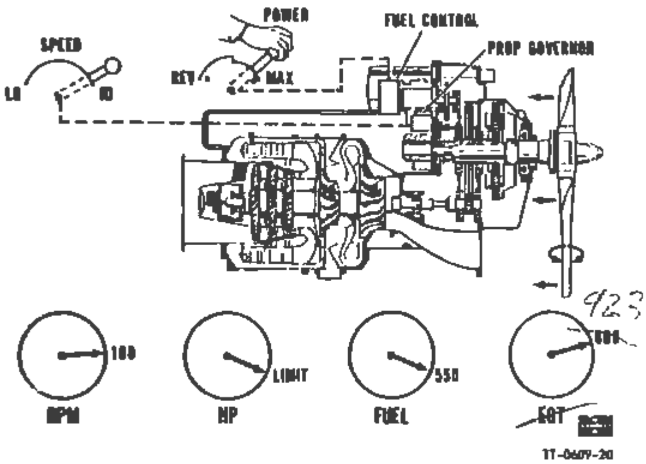
Even though the pilot has been taxiing at a low speed to keep the propeller noise down, he must advance the speed lever to the high rpm or takeoff position prior to takeoff. This recalibrates the fuel control underspeed governor to 97 per cent. The fuel control supplies the additional fuel that causes engine acceleration to 97 per cent rpm. The power lever under these conditions would be at ground idle, keeping a flat blade angle and producing no thrust in either direction.

As the engine accelerates past the 80 per cent rpm point, the speed signal to the computer will cause a number of events to transpire. The computer will activate the single red line EGT system. More will be said about this in a later section. The computer signal will also deactivate the primaries only solenoid.

Look at the instrument indications now that the engine has accelerated to 97 per cent rpm. Slightly more torque is indicated, the fuel necessary to carry the engine with the propeller at a flat blade angle to that speed is now indicated, and the resulting temperature will be indicated on the EGT gage.

It is normal to experience a sudden change in the EGT reading as the 80 per cent point is passed. When the single red line system is turned on, it will recalibrate the EGT indicating signal.

MAX POWER - TAKEOFF



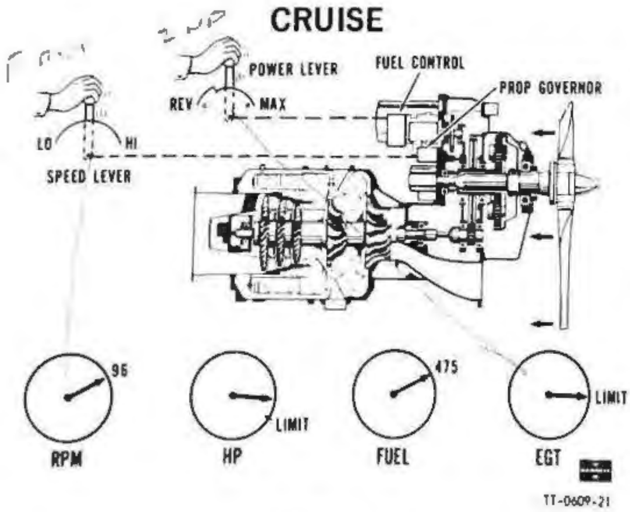
#108

You will recall that as the aircraft sat at the end of the runway, the speed lever was moved to a high rpm position and this action calibrated the underspeed governor to run the engine at 97 per cent. The power lever remained in ground idle position with a very flat blade angle. When the speed lever was moved to the full forward position, it also recalibrated the propeller governor spring to 100 per cent rpm.

As takeoff is initiated, the power lever is advanced from the ground idle position--past the flight idle detent--and pushed towards the maximum position. As we pass flight idle, the power lever controls fuel through a linkage to the fuel control. As more and more fuel enters the engine, the rpm starts to increase from 97 per cent to 100 per cent. The propeller governor--sensing the 100 per cent rpm--takes control of the propeller and holds the engine speed at 100 per cent causing the propeller to take on a greater blade angle. As additional fuel and blade angle are provided, an increase in thrust results which will cause the aircraft to accelerate down the runway.

Note the instrument readings at this point. The rpm is now being held at 100 per cent by the propeller governor. The torquemeter will be approaching the maximum rated power reading. The fuel, of course, is increasing by the action of the power lever. The temperature reading also rises.

You will remember that in the Theory of Operation section, we discussed the maximum power that we can take from the TPE331 Engine as being limited to either a torque or temperature limit, whichever comes first. The torque limit will be indicated by a red line on the torquemeter. The temperature limit, with the single red line system in operation, will be 650° Celsius. Since most of the engine applications are flat rated, the torque limit would be reached before the temperature limit for takeoff under normal ambient conditions.



#109

The efficiency of the 331 Engine is maintained under flight conditions by operating the engine very close to 100 per cent rpm. There is a small four per cent variation to allow operation of the propeller at a slower rpm for reduced noise.

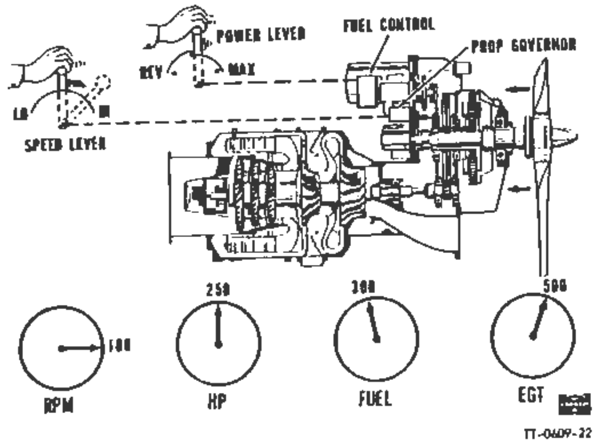
The maximum cruise rpm is 100 per cent and the minimum cruise rpm is 96 per cent. These numbers are reflected in the Pilot's Flight Operating Handbook.

To establish the cruise condition, the pilot would first pull the power lever back to reduce the temperature. He would then move the speed lever from high rpm, takeoff position, back towards the cruise position, which is marked on most quadrants.

He would observe the tachometer and limit the movement of the speed lever to obtain the desired cruise rpm between 96 to 100 per cent, but he can operate no lower than 96 per cent in the air.

Once the speed has been selected by recalibrating the propeller governor, the power lever would then be advanced to the desired cruise EGT conditions. Notice the instruments. Now that 96 per cent rpm has been selected, the propeller governor will take on the load necessary to hold the engine at that point. The power lever will be positioned to provide the fuel flow that will result in the desired EGT. Normally at cruise conditions, at altitude, the engine will be EGT limited and torque will be less than the limit. As we learned in previous discussions, this is influenced by pressure altitude, air speed and outside air temperature.

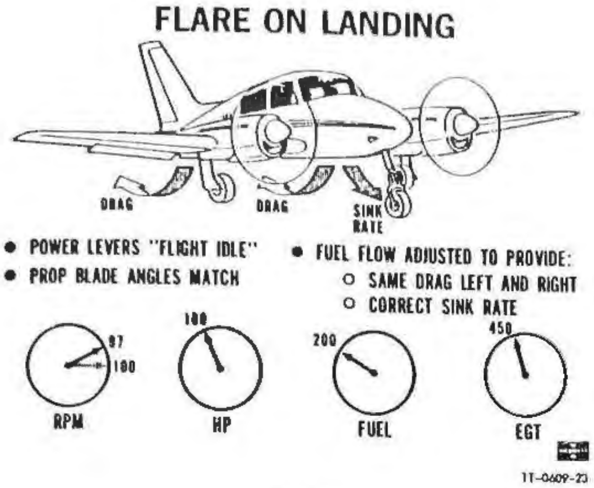
APPROACH DESCENT



#110

The Pilot's Operating Handbook instructs all operators to move the speed lever to the high rpm position prior to landing. On most quadrants, this position is identified as the takeoff/landing position. It is necessary to return the engine to the 100 per cent rpm position for landing so that the speed will be there to produce the power should the pilot be waved off and have to apply full power. The power lever is retarded in order to maintain the aircraft descent rate and speed identified by the pilot's operating procedures.

Take a look at the instruments. The rpm is back to the 100 per cent reading. As the pilot retards the power lever and reduces the fuel flow, a reduction in torque and EGT corresponding to that fuel decrease can be seen.



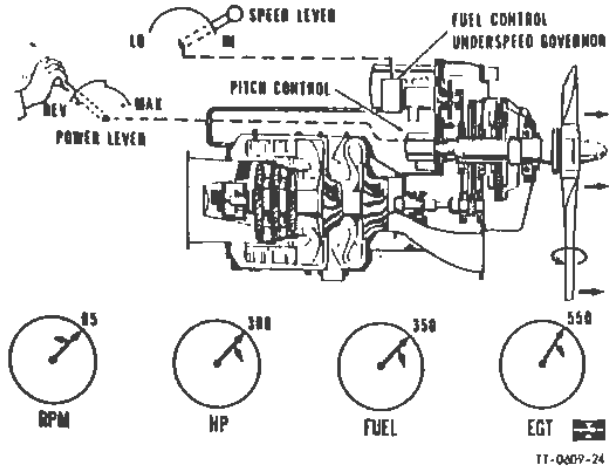
#111

As the aircraft approaches the end of the runway, the speed lever should be in the takeoff and landing high rpm position. The power lever should be retarded to the flight idle hard stop detent on the quadrant. This is the limit point at which the pilot can retard the power lever while the aircraft is still in the air.

As the aircraft flares for landing, the change in load on the propellers, as a result of a change in the propeller blade angle of attack, will cause the engine to be loaded below the power producing capability of the fuel provided with the power lever at the flight idle position.

As the aircraft touches down, lights on the cockpit panel--called "Beta Lights"--will come on indicating to the pilot that he is now at a point where he can take ground control of the propeller with the power lever. As the aircraft touches down, the rpm will drop below the propeller governor setting to the high setting of the underspeed governor. This action, along with the beta lights illuminating, indicates to the pilot that he is now in a ground mode of operation.

REVERSE THRUST · BRAKING



#112

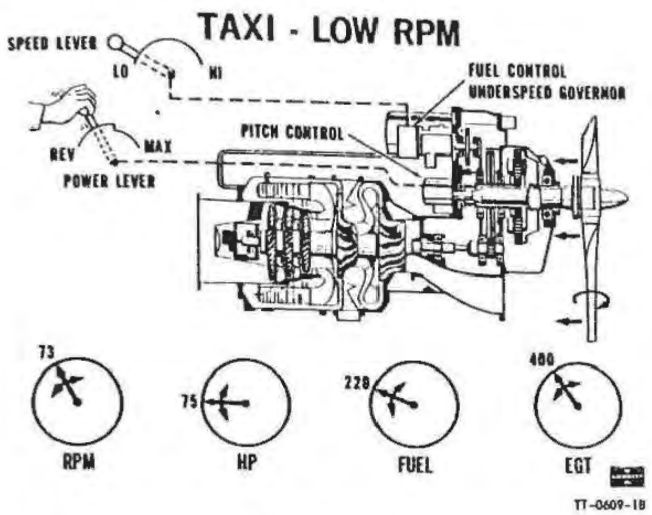
During the high speed roll down the runway, it is recommended that the speed lever be left at the high rpm position. This is necessary to ensure that power is available if needed during reverse blade angle operation. Reverse blade angle results in a reverse thrust, which aids in braking the aircraft safely to a stop.

The degree of reverse utilized should be considered in light of the runway length and runway conditions. If necessary, full reverse may be selected, however, this should be reserved for those conditions when it becomes necessary to prevent the aircraft from going off the end of the runway. If full reverse is used unnecessarily, it can shorten the life of the engine by blowing debris off the runway into the path of the engine where it could be ingested. Pilot's Operating Manuals will provide guidance in this area, indicating that the degree of reverse should be limited to the amount required under existing conditions.

Observe the instrument indications. The engine was running at 97 per cent on the underspeed governor setting. As the propeller is moved to reverse, horsepower increases. Whether the propeller blade angle is positive or negative, it still represents a load.

The increase in load results in a droop in speed from 97 per cent to perhaps 96, or even 95. It's this droop in speed that signals the underspeed governor to increase the supply of fuel, and this, of course, results in higher EGT. Normally, a one or two per cent decrease in rpm, or "Droop," can be expected as a result of this load.

CL HIGH UNTIL ON TAXIWAY TO PROTECT AGAINST ENG. BOG DOWN DURING ASYM. THRUST TURNS. (OR 85%) 3 MIN. COOL DOWN CL LOW.



#113

We need not be concerned about exceeding the engine temperature limits if the droop in rpm does not exceed these values. If for some reason, the rpm would droop sufficiently below 95 per cent, then we could expect to see a rapid increase in EGT. This overloading of the engine below safe limits is often referred to as "Bog Down."

The pilot may move the speed lever to the low rpm or taxi position after turning off the runway or, he may do it while he is still on the runway once at normal taxi speed, if he is firmly committed to the ground. As long as there is any chance that the pilot may have to apply takeoff power, the speed lever should be kept at the high rpm position.

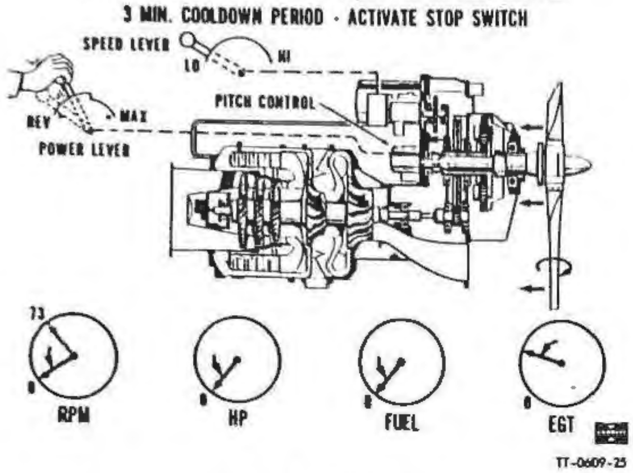
When the speed lever is retarded to the low rpm position, the underspeed governor is reset to 73 per cent rpm. The pilot may now taxi back to the terminal area by manipulation of the power lever as previously described. The pilot may move the power lever either forward or aft of the ground idle position to control the aircraft during a taxi operation.

Torquemeter, fuel flow, and temperature will reflect the changes in load caused by the position of the power lever.

The speed of the engine during this taxi operation may be selected at any point from 73 per cent to 97 per cent, depending on aircraft weight and ramp conditions. Normally, taxiing at the low speed will provide adequate power for handling the aircraft safely under these conditions with the added advantage of low propeller noise.

SHUTDOWN - PROP ON LOCKS

3 MIN. COOLDOWN PERIOD - ACTIVATE STOP SWITCH



#114

DOWTY RETOL
HOLD IN REVERSE
TO ENSURE LOCK ENGAGE.
UNTIL REST
HARTZLE RETURN TO
FI > 15%

GOOD HABIT

Once the aircraft has arrived at the parking location, the pilot is concerned with shutting down the engines. One of the most important operating procedures the conscientious pilot observes to assure the long life and trouble-free operation of his turboprop engine, is to allow for a three minute cooldown period. This reduction of the turbine temperatures prior to shutdown will minimize such possible problems as carbon deposits on seals and in fuel nozzles, as well as distortion and resulting cracks in hot end components.

If the pilot has taxied under normal light load conditions, he may consider his taxi time as part of the three minute cooldown period. Prior to shutting down the engine, the pilot must remember that he wants to return the propeller to the start locks in preparation for the next start. This is accomplished as the stop switch is activated and the engine speed decreases to about 50 per cent. During this period, the pilot will move the power lever towards the reverse position, which puts the propeller in back of the start locks. When the engine decays in rpm to less than 15 per cent, the start locks will have extended. The pilot may then return the power lever to the flight idle position. This removes the oil pressure from the propeller and allows the feathering spring to take the propeller against the lock pins. (NOTE: With a Dowty propeller, hold in reverse until rpm is below 10% in order to ensure that locks are engaged.)

Notice the instrument indications. As the fuel was shut off, rpm started to decrease.

Torquemeter and fuel flow dropped to zero at the time the stop switch was activated. The EGT reading will also decrease as the temperature drops.

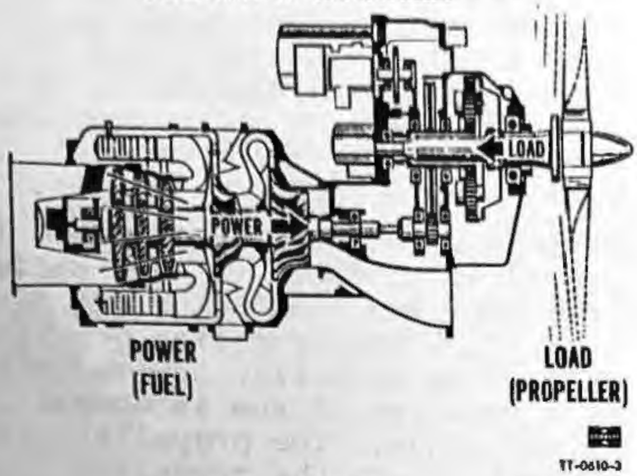
If the pilot desired to immediately restart the engine, he would be concerned with the residual EGT reading. His Pilot's Operating Manuals will instruct him that the EGT should be below a given value before initiating a restart. On a typical EGT system, the residual temperature should be less than 200° Celsius before attempting a restart.

You have now been exposed to the events that occur from initially starting the engine through flight conditions, landing and engine shutdown. Do not be concerned if you don't understand every single detail of the Operational Sequence at this point. This is just a first exposure and as we get into the individual systems and controls, you will better understand the events that we have just described.

SECTION FIVE:

POWER MANAGEMENT

YOU MUST MANAGE . . .



#117

We have seen that the controls in the cockpit serve a dual purpose during operation of the 331. There are times when either the power or speed lever controls fuel, and times when each lever controls propeller blade angle.

This picture reminds us that under all conditions of ground or flight, the two items that must be controlled are the fuel--to produce power--and the propeller--to regulate load.

The subject of "Power Management" refers to the appropriate control of power and load by the correct cockpit lever position under any condition of operation. The basic objective we are striving for in this system is simplicity of operation from the pilot's standpoint.

It has been said that the power lever provides a single lever control. This becomes evident as we review the Operational Sequence. Once the rpm has been set by positioning the speed lever, the pilot can control either the power necessary in flight, or the power and thrust direction required on the ground, by keeping his hands on the power levers only. This greatly simplifies the pilot's job.

POWER MANAGEMENT COMPONENTS

PROPELLER GOVERNOR (PG)

METERS PROP CONTROL OIL AS A FUNCTION OF RPM IN NORMAL FLIGHT RANGE

PROPELLER PITCH CONTROL (PPC)

METERS PROP CONTROL OIL WHEN RPM IS BELOW PROP GOVERNOR CONTROL RANGE

MANUAL FUEL VALVE (MFV)

METERS FUEL IN RESPONSE TO POWER LEVER DEMANDS FOR HIGH POWER

UNDERSPEED GOVERNOR (USG)

METERS FUEL TO MAINTAIN A SELECTED MINIMUM RPM

TT-0610-4

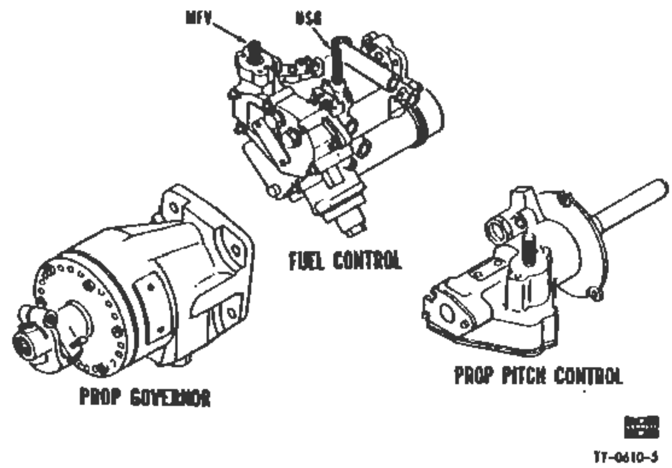
#118

Recognizing that each lever must control either fuel or propeller load under given conditions of flight or ground operation, we can identify the four major components responsible for this power management system to function.

There are two devices involved in propeller control, the "Propeller Governor" and the "Propeller Pitch Control." The propeller governor meters the propeller control oil as a function of rpm in normal flight range. The propeller pitch control meters the propeller control oil when the rpm is below the propeller governor control range.

There are also two devices responsible for fuel control, the "Manual Fuel Valve" and the "Underspeed Governor." A manual fuel valve in the fuel control meters fuel in response to power lever demands for high power. The underspeed governor--which is also part of the fuel control--meters fuel to maintain a selected minimum rpm.

FUEL/PROP CONTROLS

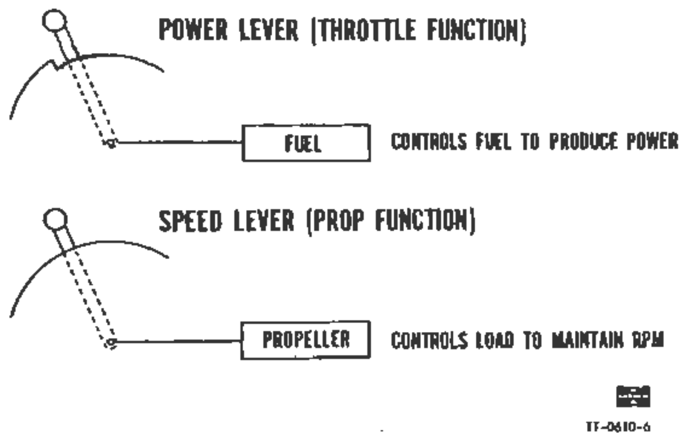


#119

Two of the four power management devices previously mentioned are located in the fuel control. The fuel control is depicted in the middle of this illustration. Notice that it has two shafts. The shaft on the left operates the manual fuel valve (MFV). The shaft on the right adjusts the underspeed governor (USG).

The picture on the left is the propeller governor and the picture in the right corner is the propeller pitch control. These two devices are responsible for controlling propeller blade angle during the appropriate period of operation.

FLIGHT OPERATION



#120

In your past experience with piston-powered aircraft, you may have become accustomed to a throttle function controlling fuel to cause the engine to produce power. With the 331, this throttle is the power lever. It is connected to the manual fuel valve shaft on the fuel control and provides the same throttle function that you are used to in flight. Under this condition of operation, the speed lever provides the typical propeller control function through connection to an adjustable propeller governor.

The propeller governor operates in principle in the TPE331 the same way it does in the reciprocating engine, by adjusting the blade angle of the propeller to maintain the selected rpm.

GROUND OPERATION

TPE331 PROVIDES:

- LOW ENGINE RPM TO REDUCE PROP NOISE DURING TAXI
- REVERSE THRUST PROP CONTROL FOR:
  - BRAKING THE AIRCRAFT
  - TAXI CONTROL

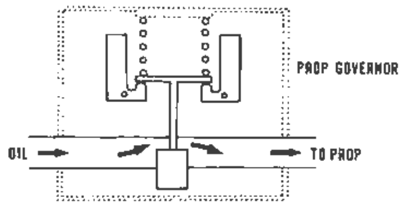
TT-0610-7

#121

Two desirable ground operation characteristics of 331 Powered Aircraft are indicated here. One is the ability to reduce engine rpm on an engine that is basically designed for constant speed operation. This action results in a desirable reduction in noise from the propeller. Secondly, it is very advantageous to be able to reverse the propeller blade angle on the ground. This causes a reverse thrust that can be used in safely braking and taxiing the aircraft. This feature becomes particularly valuable when the runway is covered with ice, or when other conditions make brake operation less effective.

REVERSE BLADE ANGLE··?

A GOVERNOR CAN NOT DO IT·!



- A GOVERNOR METERS OIL TO THE PROP AS A FUNCTION OF RPM ONLY
- A SEPARATE PITCH CONTROL IS NECESSARY TO OBTAIN A NEGATIVE BLADE ANGLE

TT-0610-8R

#122

The TPE331 Engine utilizes a conventional variable pitch, constant speed propeller. The propeller is operated primarily by increasing and decreasing oil pressure from the governor. The governor is a standard, simple flyweight metering valve.

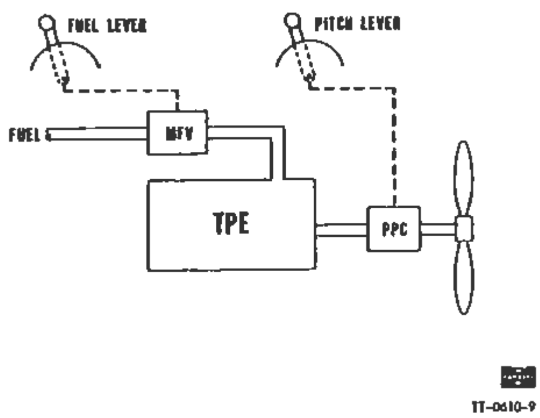
Flyweights, which move out as a result of centrifugal force, oppose a speeder spring. When these forces are balanced, the position of the metering valve will allow the correct oil pressure to be felt by the propeller.

A characteristic of this governor is that it responds to a change in rpm. It has no way of recognizing what blade angle exists and in which direction the thrust is being provided. It responds only to rpm. Since the propeller governor is attached to, and driven by, the accessory section of the engine, the speed of the engine is the speed that the governor senses.

If additional fuel were put into the engine, causing an increase in speed, that increase in speed would, in turn, cause the flyweights to move out by an increase in centrifugal force. The flyweights are pivoted to compress the spring. This pivot would change the metering valve position and reduce the oil pressure to the propeller. This would allow the propeller to move towards a higher blade angle causing an increase in load and holding the speed from further increase.

It is obvious that since the propeller governor is not capable of recognizing blade angle and selecting a reverse thrust condition, a separate system will be required to obtain a negative blade angle. The device that performs this function is referred to as a "Pitch Control."

BASIC POWER MANAGEMENT

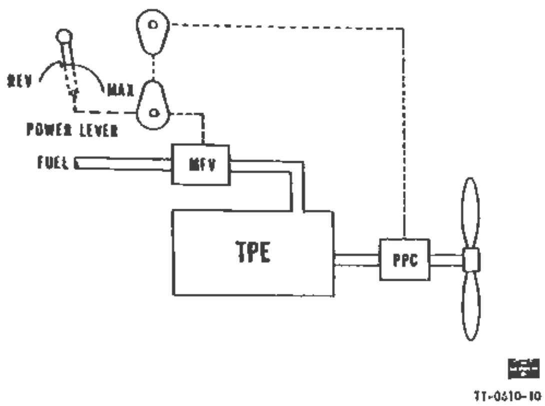


#123

Let's assume, for purposes of illustration, that the 331 Engine and it's propeller are controlled by two separate levers, one connected to a propeller pitch control and one connected to the manual fuel valve in the fuel control. Assume that the pitch lever was moved to a position to select some given blade angle, and the blade angle would remain at that point. Remembering what we have previously learned in the constant speed engine theory, as additional fuel increases power while carrying the same load, the rpm also increases. Conversely, if the fuel lever was retarded and the fuel flow reduced with the pitch control maintaining a fixed blade angle, the rpm would decrease.

If the operator of this fictitious engine were skillful enough, it is conceivable that he could advance both the fuel lever and the pitch lever at identical rates causing an increase in propeller pitch to absorb the increased power while maintaining the same rpm. This obviously would be very difficult to do.

POWER LEVER CAMS



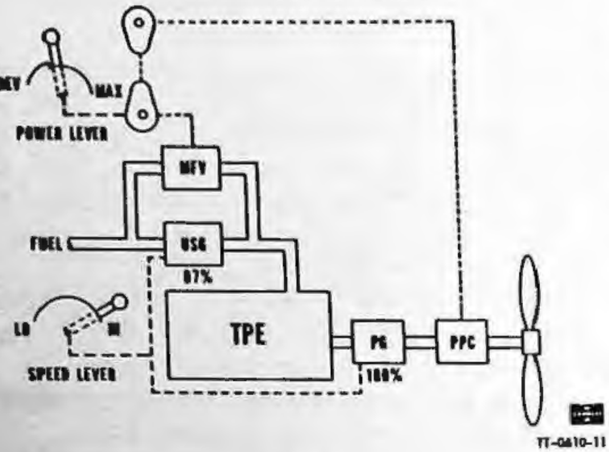
#124

Instead of relying on skillful operation of two separate levers, it is feasible that cams could be designed into the manual fuel valve in the fuel control and the propeller pitch control. These cams could be shaped as desired to give the necessary response to these devices. Both cams could then be connected to one power lever. As the power lever moved from one position to another, it could cause these specially designed cams to provide the desired signal to the fuel and propeller pitch control.

As an example of this operation, let's assume that the power lever is at the flight idle detent. As the power lever is advanced forward of flight idle to make takeoff power, the design of the propeller pitch control cam results in the propeller pitch control holding the propeller at a fixed blade angle momentarily.

If at the same time, the design of the cam in the fuel control would cause an increase in fuel, we would now recognize that with the same load, but an increase in fuel producing extra power, rpm would increase. This is an example of how the cams and the individual components can be shaped to cause the desired action when the power lever is moved.

SPEED CONTROL



#125

Let's now add a second lever to the system. The speed lever is connected to the underspeed governor in the fuel control and the propeller governor in the propeller controlling system. The speed lever recalibrates each of these governors to their respective points. As the pilot advances the speed lever to the takeoff or high rpm position, the mechanical linkage from that lever will calibrate the underspeed governor to 97 per cent rpm and the propeller governor to 100 per cent rpm. The underspeed governor will cause additional fuel to enter the engine to increase the speed to 97 per cent. The pilot would now be ready for takeoff.

With the governors calibrated to the points indicated, and the engine running at 97 per cent, the power lever would be advanced toward takeoff position. As the rpm increases above 97 per cent, it approaches the setting of the propeller governor. When the propeller governor senses 100 per cent rpm, it will take control of the propeller and cause a blade angle increase to hold the rpm by increasing load. From this point on throughout the flight, the power lever is controlling fuel. The propeller is being controlled by the propeller governor at the rpm set up by the position of the speed lever. This is called "Propeller Governing Mode of Operation."

During propeller governor mode, the underspeed governor and the propeller pitch control serve no control function.

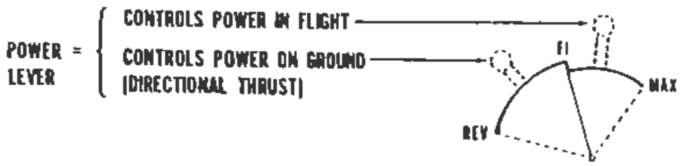
Assume now that the aircraft has landed. The pilot has brought the power lever back to reduce fuel.

When the point is reached where the fuel is no longer capable of maintaining the rpm calibrated in the propeller governor, the rpm will drop until it reaches the setting of the underspeed governor. At this point, the pilot is controlling the position of the propeller by the power lever movement of the propeller pitch control. The speed of the engine is a function of the underspeed governor providing adequate fuel to prevent the engine speed from dropping below the setting represented by the speed lever position. The name "Underspeed Governor" is appropriately selected. It limits the low speed at which the engine can run.

Remember that the propeller governor is an upper speed limiting device and the underspeed governor is a low speed limiting device.

Two terms will be used throughout the rest of this book to identify the two conditions of control we have just discussed. "Propeller Governing Mode" occurs when the power lever is forward of flight idle controlling the fuel and the propeller governor is in control of engine speed. "Beta Mode of Operation" identifies ground operation. In beta mode, the underspeed governor controls the speed of the engine by regulating fuel and the propeller pitch mechanism controls blade angle through pilot movement of the power lever. "Beta" is an engineering term used to describe propeller blade angle. It has been selected as the name for this ground operating condition, because the pilot is manually controlling the blade angle.

POWER MANAGEMENT ADVANTAGE



PILOT HAS SINGLE LEVER CONTROL FOR EACH ENGINE'S POWER FOR FLIGHT OR GROUND OPERATION = POWER LEVER

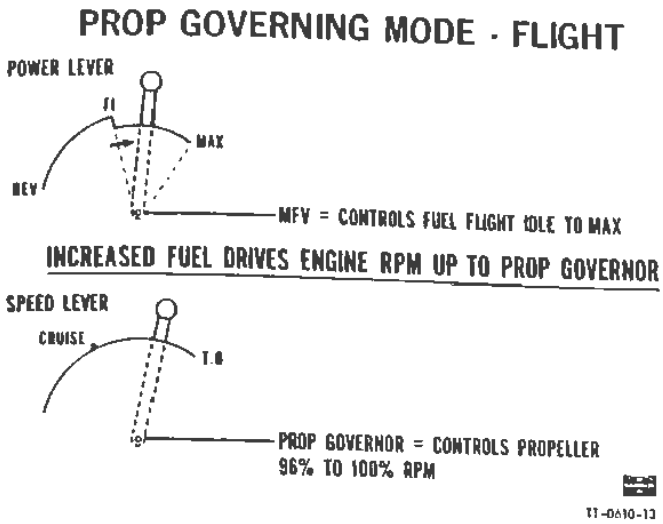
SPEED LEVER = AUTOMATICALLY CONTROLS RPM BY EITHER FUEL OR PROPELLER

TT-0610-12

#126

The advantage gained by having single lever control over the engine and propeller during the critical landing period is obvious. When the pilot has the power lever forward of flight idle, he is controlling power in flight as a function of the fuel, a typical throttle operation. The same lever controls thrust on the ground when moved aft of flight idle. This single lever control eliminates the need for the pilot to be moving his hands from control to control during critical landing periods.

The power lever represents a priority that can be selected by the pilot. For example, when he decides to control fuel for takeoff, he can move the power lever up into the propeller governing range of operation. When he decides to take control of the propeller on the ground, he can do so by moving the power lever back into the beta range. So the pilot has the option to decide which function he wants to control. The speed lever will automatically take care of the other needs.

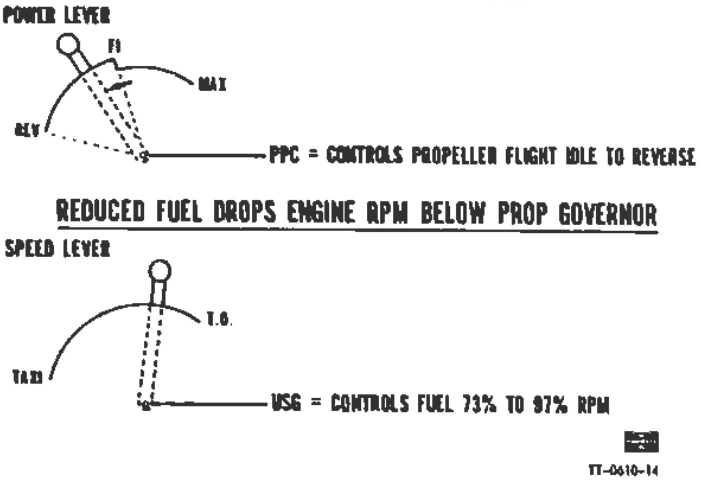


#127

Let's review propeller (or "Prop") governing mode once more. Recognize that the power lever has been moved forward of flight idle, as shown in this drawing. The connection of the power lever to the manual fuel valve permits control of increasing or decreasing amounts of fuel to the engine. The increasing fuel condition will drive the engine rpm up into the range of the propeller governor. The speed lever will select the calibration point of the propeller governor desired by the pilot.

The total range of speed selection is represented by the position of the speed lever from 96 to 100 per cent rpm. During any propeller governing mode of operation, this four per cent difference represents the total speed adjustment available to the pilot. It is clear that the engine operates at, or very close to, its maximum efficiency rpm.

BETA MODE · GROUND



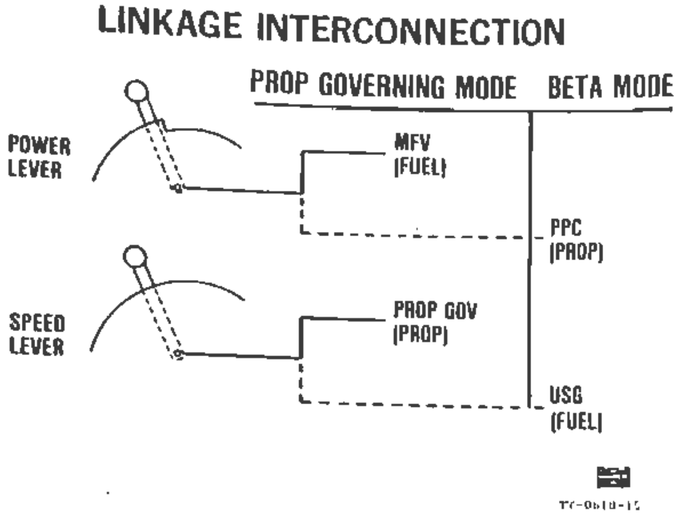
#128

All Pilot's Operating Handbooks caution that the pilot should never bring the power lever into the beta range on multi-engine aircraft unless the aircraft is on the ground.

When the pilot desires to control propeller blade angle to regulate the direction of thrust on the ground, the power lever is brought behind the flight idle detent. From flight idle back to reverse, the pilot is controlling the blade angle all the way from a positive flight idle blade angle back to a preset negative pitch angle.

Retarding the power lever behind the flight idle detent also reduces the fuel that it had been providing via the manual fuel control. So the rpm drops below propeller governor authority and the fuel is now a function of the underspeed governor as calibrated by the position of the speed lever.

The underspeed calibration range varies from the taxi or low rpm position to takeoff, typically 73 per cent. Taxi rpm varies with aircraft installations. It may be as low as 65 per cent.



#129

It is necessary for each cockpit lever to have connections with both fuel and propeller governing components. This chart illustrates the power lever connections to two such devices, the manual fuel valve in the fuel control and the propeller pitch control. Also shown are the speed lever connections to a propeller controlling governor and a fuel controlling underspeed governor.

The columns on the right side of this chart indicate the components that are responsible for propeller or fuel control in either propeller governing or beta mode.

Although this system might appear somewhat complex at this point, it should be remembered that the advantages it provides through the single lever control system result in much simpler and safer operation for the pilot. As should be evident by now, these advantages are: the ability to adjust a constant speed engine to lower speeds to provide quieter propeller operation, and the option of selecting a reverse blade angle.

SUBJECT:

SECTION 4 - OPERATIONAL SEQUENCE
SECTION 5 - POWER MANAGEMENT

WORKBOOK EXERCISE 3

1. The basic function of the speed lever is:
   a. To select the operating speed of the engine in the air and on the ground.
   b. To control the power produced at a given engine speed.

2. The basic function of the power lever is:
   a. To select the operating speed of the engine in the air and on the ground.
   b. To control the power produced at a given engine speed.

3. During normal in-flight operation, the power lever would be operated between which of these positions?
   a. Flight idle to reverse.
   b. Flight idle to maximum.
   c. Ground idle to maximum.
   d. Reverse to maximum.

4. Before making a ground start, the propeller should be:
   a. In the feather position.
   b. On the start locks.
   c. In the reverse position.
   d. At the flight idle position.

5. The position of the engine control levers for a normal ground start is best described by which of the following?
   a. The speed lever at high rpm and the power lever slightly behind ground idle.
   b. The speed lever at low rpm and the power lever midway between flight idle and maximum.
   c. The speed lever at low rpm and the power lever slightly behind flight idle.
   d. The speed lever must be at low rpm, but the position of the power lever is not important.

WORKBOOK EXERCISE 3

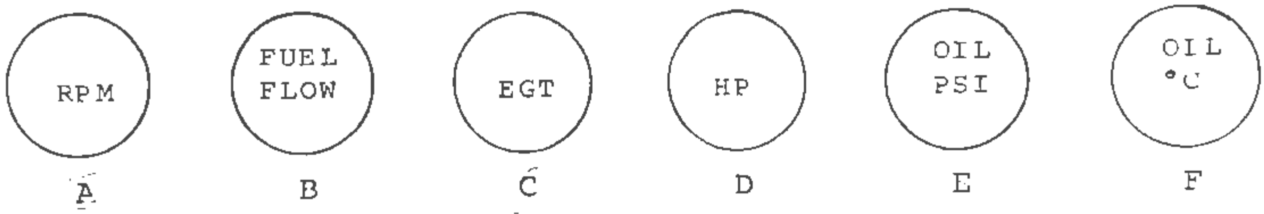
6. During normal starting, when are fuel and ignition supplied to the engine?

   a. Automatically at 10%.
   b. The ignition system is actuated when the starter is energized and fuel is supplied at 10%.
   c. Both fuel and ignition are actuated when the starter is energized.
   d. Automatically at 18% to 28%.

7. While making an engine start, what provides indication of "lightoff"?

   a. 10% rpm indication.
   b. A sudden increase in fuel flow.
   c. Audible ignition.
   d. A rise in turbine temperature.

8. After lightoff and during acceleration, which of the following indicators would be of primary concern to the operator?



   a. Indicators C and A.
   b. Indicators B and D.
   c. Indicators E and F.

9. Which of the following best describes the events that occur at approximately 60% rpm?

   a. The starter is de-energized.
   b. The ignition is shut off.
   c. The oil vent valve closes.
   d. All of the above.

10. As the engine accelerates and approaches a stabilized on-speed condition, the operator would observe:

   a. A reduction in fuel flow due to the change in P3 pressure.
   b. A reduction in fuel flow due to the action of the underspeed governor.
   c. No change in fuel flow because of the decreased P3 pressure.
   d. An increase in turbine temperature due to a decrease in fuel flow.

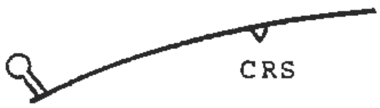
WORKBOOK EXERCISE 3

11. After reaching the recommended stabilized on-speed condition, to release the propeller start locks, the operator would:

a. Move the power lever towards maximum.
b. Move the speed lever to high rpm.
c. Move the power lever towards reverse.
d. Do nothing. The start locks will release automatically once an on-speed condition has been reached.

For each combination of power lever and speed lever positions as shown in questions 12 through 16, indicate which components will be controlling fuel (power) and propeller (load) by selecting your answer from the list below.

~~a.~~ PG and PPC
b. MFV and PG
~~c.~~ MFV and USG
d. USG and PPC

	Power Lever	Speed Lever	Answer
12.			b
13.			d
14.			b
15.			d
16.			d

WORKBOOK EXERCISE 3

17. The power lever is mechanically connected to the:

  a. PPC and PG.
  b. MFV and PPC.
  c. MFV and USG.
  d. PG and USG.

18. The speed lever is mechanically connected to the:

  a. PPC and PG.
  b. MFV and PPC.
  c. USG and MFV.
  d. USG and PG

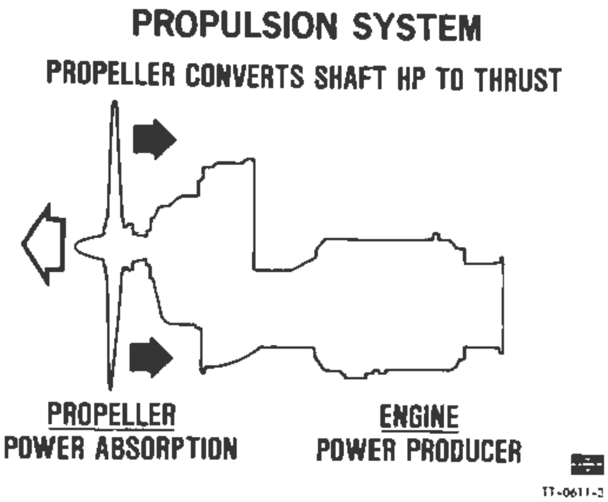
19. The priority of whether the power lever controls either fuel or propeller is determined by the position of the:

  a. Speed lever.
  b. Power lever.
  c. Both levers.

SECTION SIX:

PROPELLER CONTROLS

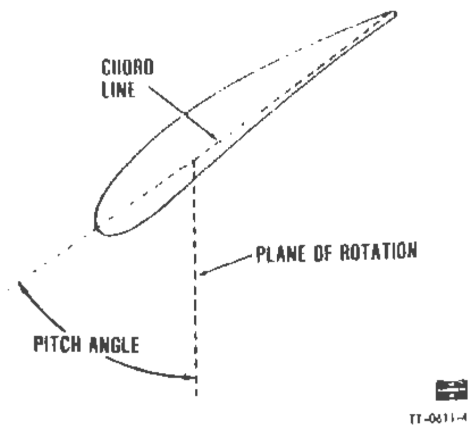
In the first five sections of this book, we have been concerned with establishing the theory and basic fundamentals of TPE331 Engine operation. The ability to effectively maintain and troubleshoot the engine is heavily dependent upon an understanding of individual systems within the engine and their components. Beginning with this section, we will examine the details of these various systems and their components.



#134

It is obvious that the engine, by itself, does not provide the thrust necessary to move the aircraft. The engine produces the power, but that power must be absorbed and converted into thrust. This is where the propeller comes in. The propeller converts the rotational torque energy of the engine output shaft into usable thrust to move the aircraft.

PITCH ANGLE



#135

In order to establish a consistent base for future discussion of the propeller, it will be useful to define and describe some of the terms and basic operations involved in the propeller system.

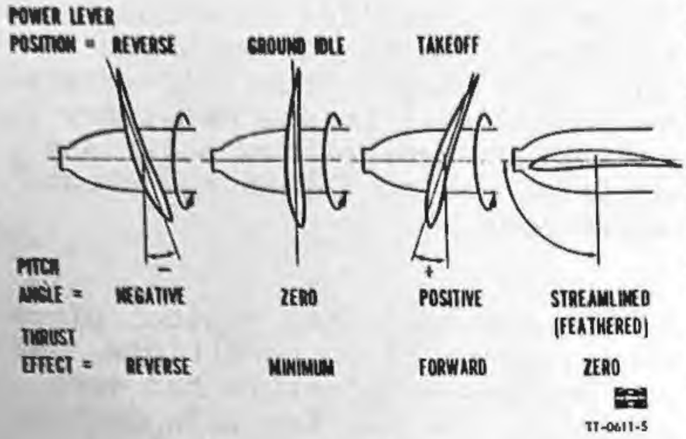
The propeller blade, as shown here in cross section, constitutes an airfoil. It operates very much like the wing of the aircraft. The distance over the top, or forward edge, of the blade is greater than the distance over the bottom. The increase in velocity of air over the front face of the blade creates the lift that causes thrust to be produced.

The "Chord Line" is an imaginary center line that goes from the center of the leading edge to the center of the trailing edge.

The "Pitch Angle" represents the angle in degrees between a line representing the plane of rotation and the chord line. An increase in pitch angle would cause a greater degree of thrust and a reduction in pitch angle would result in less thrust.

If an excessively high pitch angle is selected, the blade can actually stall like an airplane would stall if the relative angle of the wing were increased beyond the capability to keep the airplane flying. The propeller control system limits the travel of the propeller blade to a given range of pitch angle.

PROPELLER THRUST RANGE



#136

The maximum selected range of blade pitch angle is a function of internal stops within the propeller. These angles range all the way from a full reverse, negative blade angle, to a fully streamlined feathered position.

No attempt will be made in this section to cover the maintenance actions involved in internal construction of the propeller. These instructions should obviously be obtained from the aircraft maintenance manual.

Across the top of this picture, the power lever positions are indicated. You can see that when the power lever is in the full reverse position, the pitch angle created will be negative. The thrust created by a blade at this angle would be in a reverse thrust direction, obviously not to be used in flight. Before looking at the power lever positioned at ground idle, remember the definition of idle. When the turboprop engine is at idle, it means the engine is at minimum load. At ground idle, the pitch angle would be as close to zero as practical, and the thrust would be at a minimum. This is the typical position of the propeller when the aircraft is sitting stationary on the ground.

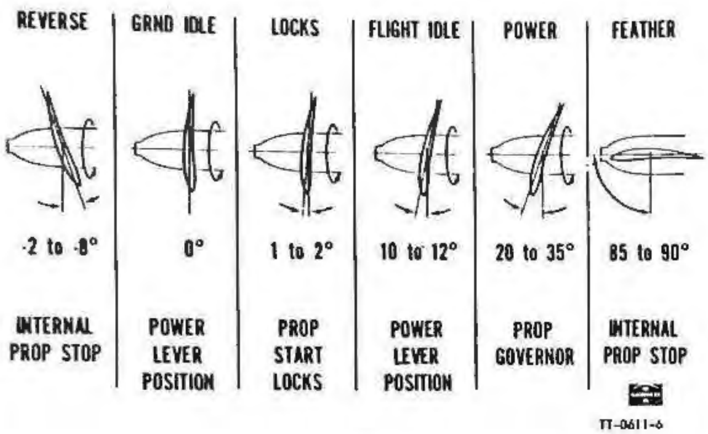
As the power lever is moved toward the takeoff position, the propeller blade angle goes in a positive direction, creating a forward thrust that moves the aircraft.

Under conditions of emergency shutdown in the air, the propeller blade angle goes to a maximum pitch angle of approximately 90 degrees. With the engine shut down, it is important to streamline the blade to the direction of flight.

This is the feathered position and results in a minimum drag.

Since the propeller is mechanically capable of operating anywhere in this full range--from full reverse to feather--it is now necessary to review the typical key positions utilized during flight and ground operations.

TYPICAL KEY POSITIONS



#137

OSC CHECK
LOCKS
CL HI [illegible]
PL INC TO RPM
STABILIZE. (5 SEC. LIMIT)
105.5 ABS. MAX.
PL TO FIREWALL
PL BACK

This chart indicates typical pitch angles under given conditions, and the devices responsible for each position. In the far left portion of this diagram, reverse blade angle has been selected. The internal propeller stop is responsible for limiting full reverse travel from two to eight degrees negative. This value is determined by the aircraft manufacturer, and the propeller internal stops are adjusted accordingly.

When minimum thrust is desired, the power lever is moved to the ground idle position.

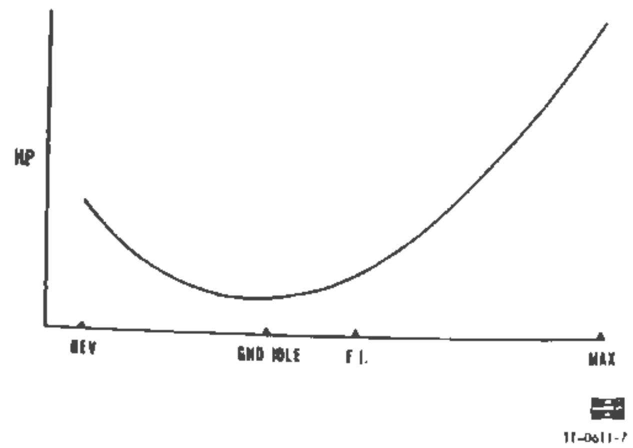
During start, the propeller blade angle will be held by blade start locks. Typically, these start locks will be adjusted to maintain approximately one to two degrees positive blade angle. This results in a minimum load, but still provides airflow across the engine nacelle for cooling purposes.

When the propeller is taken off the locks, and the power lever is at flight idle position, the blade angle will be about 10 to 12 degrees positive. The flight idle blade angle for any given aircraft application is determined by the aircraft manufacturer during flight tests.

As the power lever is advanced for takeoff, the increased fuel flow to the engine will increase engine speed, eventually reaching the propeller governor set point. The blade angle will then be a function of the propeller governor. Of course, this is a rather wide range, dependent upon the power being produced.

The final position--shown in the far right portion of this picture--is the result of an emergency shutdown. If a malfunction should necessitate stopping the engine, the appropriate controls are moved in the cockpit and the engine is shut off. The propeller is allowed to go to a full feathered position. This position is limited by the internal stop within the propeller itself. The specific angle that the propeller will assume in a fully feathered position is, again, the result of flight testing the aircraft. The pitch angle selected should result in a minimum drag, but it should not go to a point that would cause reverse rotation of the engine.

TYPICAL HP vs PITCH ANGLE

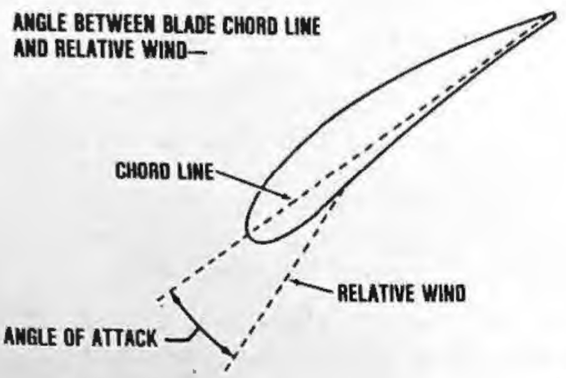


#138

This curve represents a typical power demand from the engine to support the various blade pitch angles. It can be seen that the minimum horsepower required is at the ground idle position where, obviously, the pitch angle is at a minimum point. As full reverse is selected, we can see that the torquemeter indicates an increase in horsepower. As the power lever is moved from ground idle, through flight idle, towards takeoff condition, notice that the blade angle is greater, requiring a greater horsepower.

In a previous section, we stated that maximum power is limited in the turboprop engine by either torque or temperature. It can be seen from this curve that we do not expect to approach those torque or temperature limits in a full reverse operation. This is normally pertinent only in a condition of takeoff. Typically the horsepower requirements in full reverse would be less than half of that in takeoff. Of course, this is a function of the degree of blade angle that has been selected by the aircraft manufacturer for full reverse operation.

ANGLE OF ATTACK



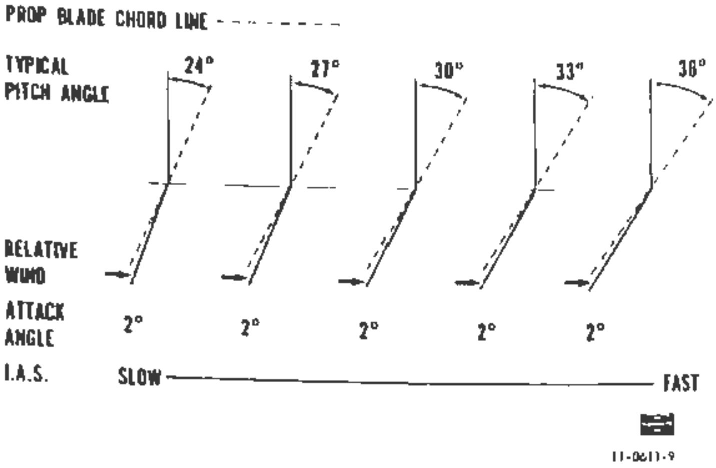
#139

Pitch angle was previously defined as the angle between the chord line of the propeller blade and the plane of rotation. Now we need to define another term, "Angle of Attack." The angle of attack is the angle between the blade chord line and the relative wind that passes over the blade.

To understand the part angle of attack plays in propeller operation, think of the following example. Assume that your aircraft had a fixed pitch wooden propeller. The pitch angle of this propeller would always remain the same. When the aircraft is sitting at the end of the runway ready for takeoff, the relative wind that surrounds the aircraft is stationary. The angle of attack would be essentially the same as the pitch angle. As the brakes are released and the aircraft starts to move forward, the angle of attack would decrease, due to the forward motion of the aircraft resulting in a change in the relative wind angle. The reduction in load on the propeller which would result from this decreasing angle of attack would, in turn, create increased rpm on the fixed pitch propeller application.

During an approach in this aircraft, the pilot would retard the power lever to the position that would result in a normal rate of descent. As the aircraft descended, the angle of attack would be very low, as a result of the aircraft speed. As the nose of this aircraft is pulled up during flare for landing, an increase in propeller angle of attack would result. From the further reduction in forward speed, this increased angle of attack would create an increased load causing the engine to drop in rpm.

CONSTANT LOAD vs INCREASED AIRSPEED



#140

The numbers on this chart can be used to illustrate typical pitch angle changes that occur as the aircraft increases or decreases in speed in an effort to maintain a constant angle of attack and a constant load on the engine. The propeller we are now considering is obviously not a fixed pitch propeller. It is a typical hydromechanical, constant speed, governor-operated propeller.

On the bottom of the chart you can see that indicated air speed is represented as movement from a slow flight condition to a faster condition. The angles indicate that, in order to maintain a constant two degrees of attack, and the subsequent constant load, the propeller control system would have to change to an increasing pitch angle condition as the aircraft increased in speed. Remember again the fundamentals of a constant speed engine. When the load matches the power, rpm remains constant.

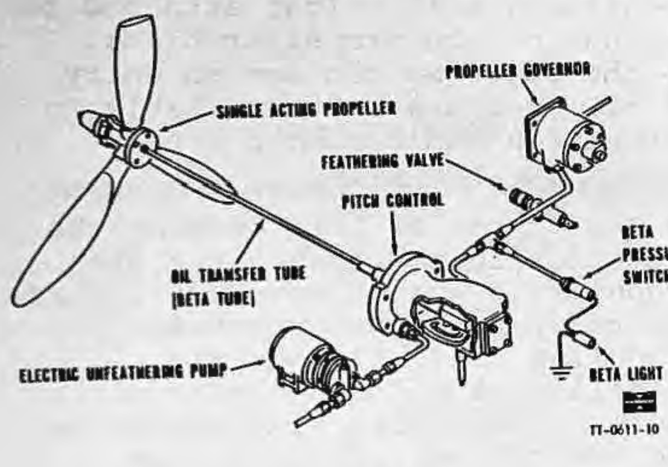
Let's assume that the aircraft is flying straight and level at altitude. The pilot has set the speed lever to calibrate the propeller governor to maintain 100 per cent rpm. He has also set the power lever to the desired power indicated by the torque or temperature gage.

If the pilot does not change the settings of the power lever or speed lever, but moves the aircraft control forward to drop the nose of the airplane, obviously the speed of the aircraft will increase. This will relieve the load of the propeller by reducing the angle of attack with the increase in forward speed.

This, in turn, would tend to increase the rpm of the engine and would necessitate the propeller governor selection of a higher pitch angle to hold the engine at 100 per cent rpm.

Conversely, if the pilot raises the nose of the aircraft, the angle of attack and the load will increase, resulting in a reduction of rpm. The propeller governor would reduce the pitch angle to maintain 100 per cent rpm. This is an example of typical propeller governor operation. The blade pitch angle is adjusted in an attempt to maintain a constant load, resulting in a constant engine speed.

PROP SYSTEM COMPONENTS



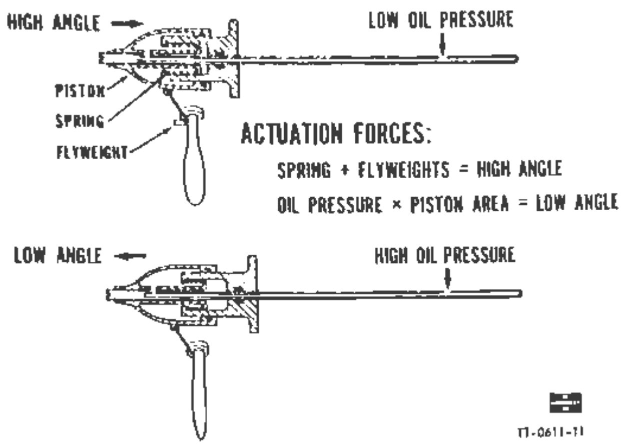
#141

In order to understand the propeller control system, it is helpful to be familiar with the components within that system. Starting at the upper left, you see the typical single acting propeller. Since that propeller is operated by oil pressure, it is necessary to have an oil transfer tube connecting it to the control devices. This tube is often referred to as the "Beta Tube." The beta tube is inserted into a device called a "Propeller Pitch Control." On the left side of the propeller pitch control you can see that a source of oil from the oil tank can be provided to the propeller by the action of an aircraft installed "Electric Unfeathering Pump."

In the upper right hand corner you can see the propeller governor that receives the supply of oil from the engine lubrication system and provides it past the "Feathering Valve," to the propeller pitch control.

Between the feathering valve and the propeller pitch control is an oil operated "Beta Pressure Switch." This switch illuminates a beta light in the cockpit panel. These are the major components in the propeller control system.

SINGLE-ACTING PROPELLER



#142

The major components of a typical single acting propeller are indicated in the upper portion of this drawing. The piston, or movable part, is sometimes referred to as the "Dome." The piston operates in conjunction with a cylinder that is bolted to the propeller shaft. This drawing indicates a large heavy spring within the piston and cylinder arrangement. It also reveals, at the blade connection to the propeller, a flyweight attached to the hub of the propeller blade. To the right we can see an entry of oil pressure made available to the piston and cylinder area within the propeller.

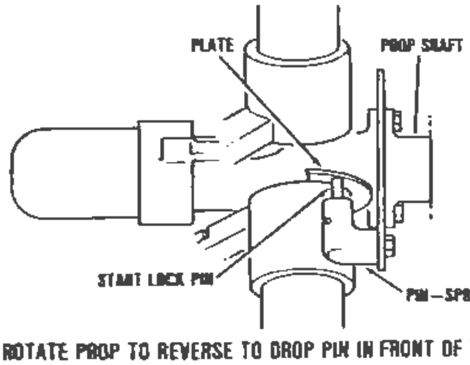
In the center of this drawing the actuation forces that cause the propeller blade to move are listed. The heavy spring within the propeller tends to move the propeller blade into a high pitch angle. This force is assisted by the centrifugal action on the flyweights attached to the blade. The combination of the spring force, plus the flyweight force, attempts to move the propeller blade towards the high angle. If these forces are unopposed, the propeller will go to a full feathered position. The bottom half of the formula reveals that oil pressure times the effective area of the piston attempts to move the blade to a low pitch angle.

Notice that high oil pressure is being introduced into the piston and cylinder forcing the cylinder to extend to the left. The blade will rotate toward a low pitch angle. Whenever the spring plus flyweight force is equaled by the oil pressure times the piston area, the propeller blade angle will stay at that given position.

As we examine these forces, we can see that the one element of the entire formula that can be adjusted by the control system is oil pressure. As the top picture illustrates, when the oil pressure is low, the propeller blade will move towards a higher pitch angle. When the oil pressure is high, the propeller blade will move towards a low pitch angle. It should be obvious then that control of the propeller involves a control system that adjusts oil pressure.

START LOCKS

PROPELLER MUST BE AT MINIMUM BLADE ANGLE PRIOR TO STARTING ENGINE



ROTATE PROP TO REVERSE TO DROP PIN IN FRONT OF THE PLATE

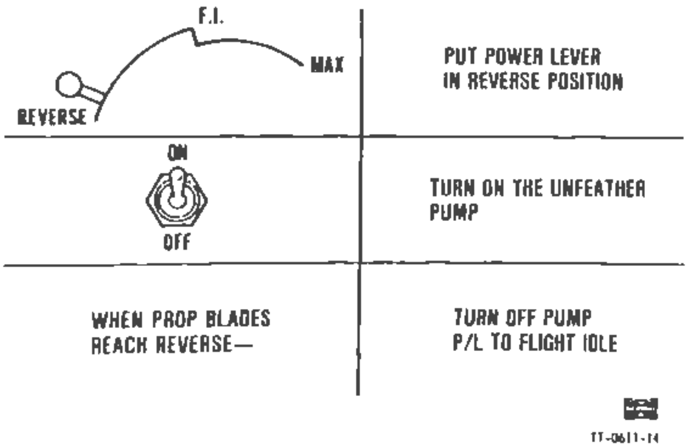
#144

In the start sequence section, you learned that the propeller must be held at a very low blade angle in order for the engine to be started satisfactorily. This low blade angle reduces the load requirement on the electric starter motor and allows easier engine acceleration to governed operation. If a start is attempted with the propeller in a fully feathered position, excessive load will result in extremely high temperatures in the turbine section.

This diagram shows the major components of the start lock system. A plate is attached to the hub section of the propeller blade. The start lock pin is in a pin spring housing and, in this illustration, the pin is being held against the plate by the spring within the housing.

Each blade on the propeller has the same arrangement of the start lock pin in its housing and a plate attached to the hub of the blade. If the propeller were rotated to reverse under these conditions, the plate would rotate to the right until the pin could be extended in front of the edge of the plate. When the force that moves the propeller blade to reverse is removed, the heavy feather spring in the piston causes the propeller to rotate towards a high angle, or feathered position. When the end of the plate contacts the pin, the limit of travel is reached. This position would hold the blade angle at one to two degrees positive blade angle and would represent a very light load on the engine.

TO PUT PROP ON THE LOCKS



#145

Aircraft maintenance manuals fully describe the procedure for installing or removing a propeller from the engine. The Hartzell propeller is always installed or removed with the blades in a feathered position. This prevents the load of the heavy feather spring from distorting the start lock arrangement.

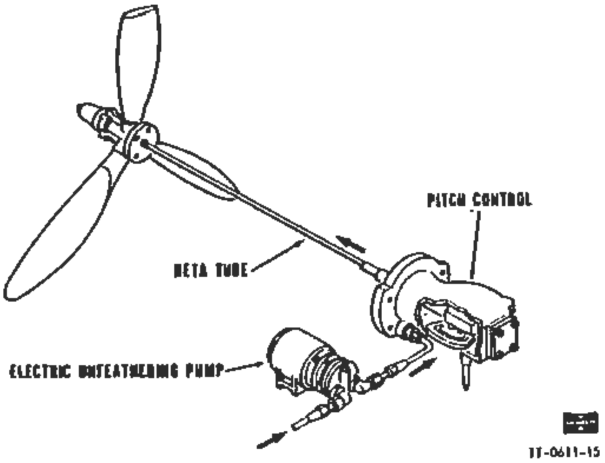
In the case of a newly-installed propeller, or if the pilot had failed to put the propeller on the locks at the last shutdown, the propeller must be put on the locks before attempting a start. The procedure for accomplishing that task is illustrated here.

The power lever is placed in the reverse position and the unfeathering pump is turned on. This supplies oil pressure to the propeller, causing it to rotate to the full reverse position.

In the process of moving to reverse, the plates on the hub of the propeller blade will rotate past the start lock position and the pins will be extended. Once the propeller reaches full reverse, the unfeathering pump is turned off and the power lever returned to the flight idle position.

The oil will leave the propeller and the feathering spring will take the blade towards a higher angle until it contacts the start locks. As long as the power lever is kept forward of ground idle, the propeller will stay on the locks during the start and acceleration procedures.

UNFEATHER



#146

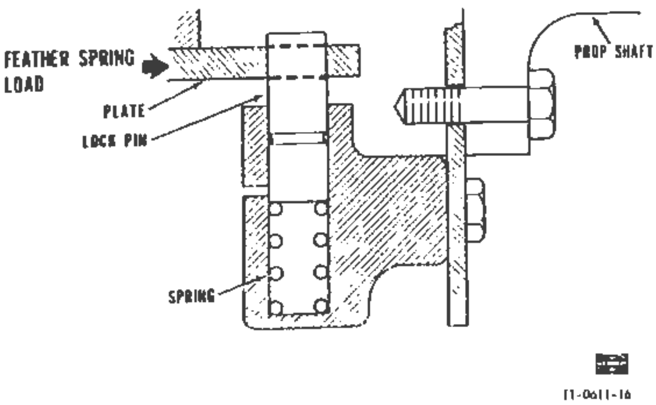
To accomplish the unfeathering procedure just described, the aircraft installed electric driven unfeathering pump was utilized. This pump provides oil from the engine oil supply tank through the propeller pitch control and beta tube to the piston assembly on the propeller. This action drives the propeller towards the reverse position. This unfeathering system is also used to start a 331 Engine while the aircraft is in the air.

In a normal ground start condition, the starting power is provided by an electric starter motor. You will recall that the propeller at that time is on the locks and offers very little resistance to being turned. If the engine were shut down in the air and the propeller allowed to go to the full feathered position, it is obvious that the starter motor could not provide enough power to crank the engine with the propeller in such a position.

Therefore, the normal starting procedure in the air involves the use of the unfeathering pump to provide a supply of oil through the propeller pitch control and the beta tube, to the propeller, that will start moving the propeller out of feather. As the propeller moves out of feather, the blades will be rotated by the windmilling action of the air stream flowing across the propeller. This action provides a cranking torque to the engine. With the appropriate control settings, the engine will light off, accelerate, and be back in operation.

To summarize, the unfeathering system is used for two principal operations. First, it puts the propeller on the locks under a static condition on the ground. Second, it's used to unfeather the propeller to provide the cranking power necessary for an air start.

START LOCKS ENGAGED



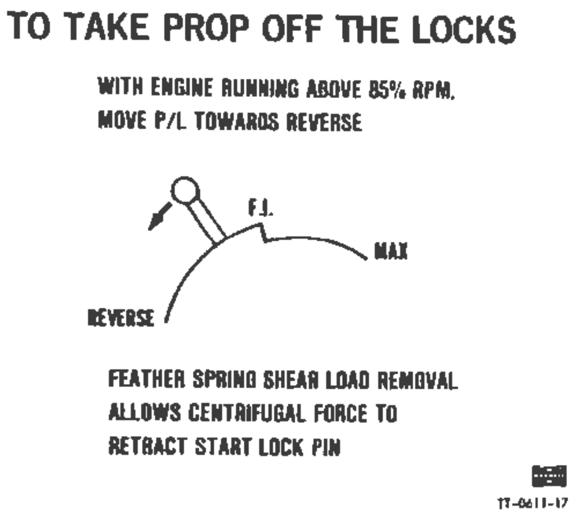
#147

This picture illustrates lock pin position during start lock engagement.

At this point in time, the lock pin is extended and bears against the end of the plate. The strong feather spring in the propeller assembly is trying to take the propeller toward the high blade angle. This force is reflected in a shear load on the side of the pin that keeps the locks engaged even during the engine starting and acceleration procedures.

As long as the power lever is forward of the ground idle position, the locks will remain engaged at any speed.

The small hole located in the left side of the lock pin housing can be used in certain maintenance operations to locate a pin that will keep the lock pin retracted so that the propeller can be operated through its full range of cycle during such maintenance activities as ground checking the blade angle.

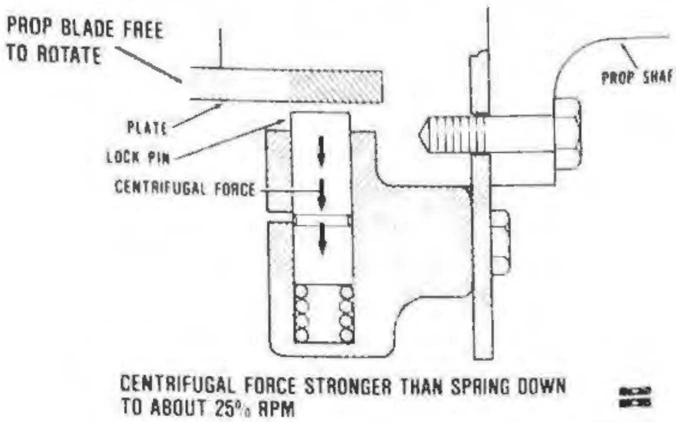


#148

After the engine has been started and has accelerated to governed speed, the propeller may be taken off the locks by merely moving the power lever towards the reverse position. This can be done at any speed, but most aircraft manufacturers will recommend in the Pilot's Operating Handbook that the speed lever be advanced to above 85 per cent rpm before attempting to take the propeller off the locks. This assures adequate oil pressure which, of course, is a function of the speed of the pumps.

The oil pressure in the propeller will move the blades toward reverse, removing the shear load that has been applied by the feather spring. As soon as the shear load is removed, centrifugal force acting on the mass of the start lock pin will overcome the small spring in the start lock housing and retract the pin.

START LOCKS DISENGAGED



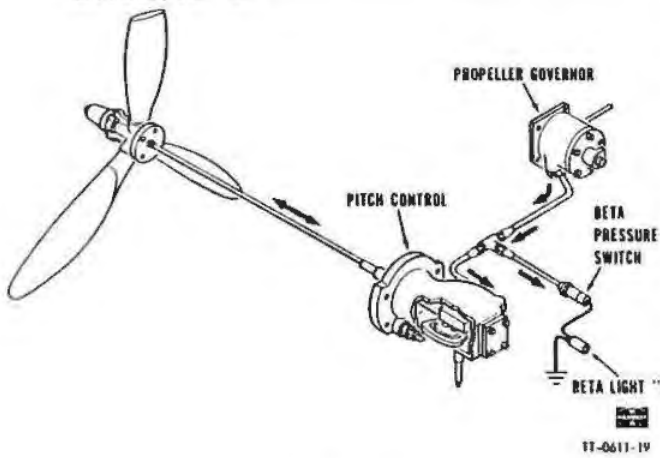
#149

This centrifugal force will be sufficiently strong to hold the pin in the retracted position under all engine operating conditions. There is no possible way that the pin can be reengaged while the engine is still running.

As the engine coasts down in speed after shutoff, the rpm must be less than 25 per cent rpm before the spring force will be strong enough to overcome centrifugal force and extend the pin into position on the Hartzell propeller.

It is important to remember that lock pins should never be oiled. They should be kept clean and free, so they can operate without binding. The use of oil is detrimental because it may collect debris which can cause the lock pin to stick in a given position.

GROUND OPERATION - BETA MODE

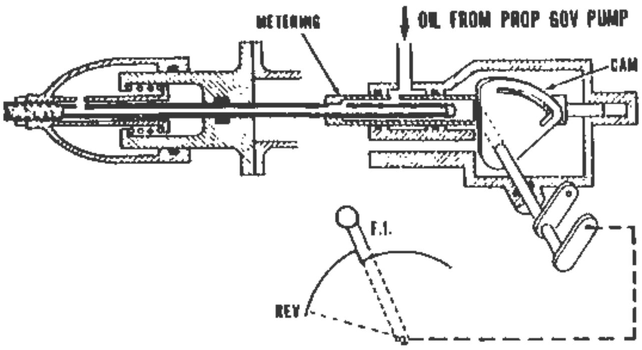


#150

The propeller governor contains a pump that takes lubrication oil from the engine system and boosts it to the pressure necessary to operate the propeller. This oil pressure is made available to the propeller pitch control and is then metered to the propeller to obtain the desired action.

Located between the propeller governor and the propeller pitch control is the beta pressure switch. This is an oil operated switch that turns on the cockpit panel beta light when it senses high oil pressure. In beta mode of operation, the beta light will be on.

BETA MODE



PPC FUNCTIONS AS A VARIABLE LOW PITCH STOP

TT-0611-20

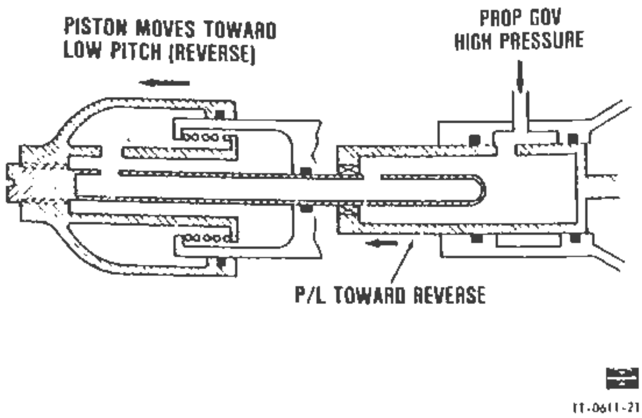
#151

In the Power Management section of this book, we discussed the fact that the power lever is mechanically connected to both the propeller pitch control and the manual fuel valve in the fuel control. This picture identifies that physical connection from the power lever to the cam within the propeller pitch control.

Movement of the power lever results in a rotation of the cam. The slot in the cam is attached--by virtue of a pin--to a follower sleeve. The follower sleeve can be made to extend or retract within the propeller pitch control as a result of the cam rotation.

The function of the propeller pitch control in beta mode is to meter the oil from the propeller governor pump into the propeller through the beta tube. This metering takes place at the point indicated in this drawing. The series of illustrations that follows will identify how the propeller pitch control functions as a variable low pitch stop. Remember that a propeller governor cannot select reverse blade angle because it senses only rpm. We will now see how the propeller pitch control is able to select a reverse blade angle by limiting the travel of the propeller in a low pitch direction.

METERED PRESSURE HIGH



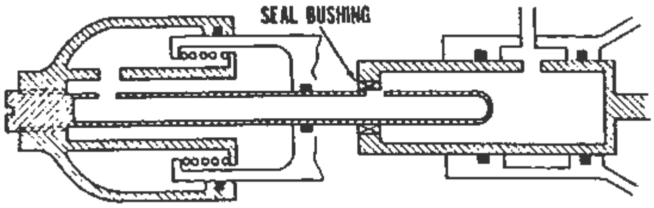
#152

The assembly on the right side of this drawing represents a portion of the propeller pitch control. As the arrow notes, the power lever is in a reverse position and the cam has moved the follower sleeve in the propeller pitch control to the position shown. Propeller governor high pressure oil is available to the propeller pitch control as indicated by the arrow on the top right side. The same pressure is extended into the inside of the follower sleeve and through holes within the beta tube.

The beta tube--acting as an oil transfer tube--carries the oil pressure to the left into the piston area of the propeller. You will recall that the increase in oil pressure will cause the propeller piston to move to the left and rotate the blades toward a low pitch angle. In this case it would continue on until reaching the full reverse position as limited by the propeller internal reverse stop.

Notice that the left end of the beta tube is a threaded connection attached to the piston of the propeller. As the high oil pressure causes the piston to move left, it would then pull the beta tube with it. Since the beta tube is attached to the propeller, it rotates with the propeller. The propeller pitch control does not rotate. Some of the oil will provide lubrication at this point to prevent metal-to-metal wear.

HYDRAULIC LOW PITCH STOP

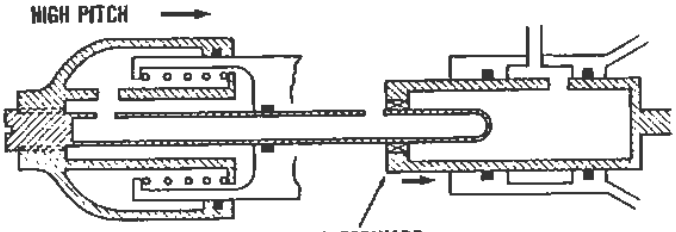


#153

Let's assume that we have selected a blade position short of the internal reverse stop. As high oil pressure moves the propeller piston to the left, the beta tube also moves, since it is attached to the piston by threads. As the beta tube moves left, a point is eventually reached where the hole in the beta tube approaches the seal bushing in the follower sleeve. This position is shown here.

When the metered oil pressure is reduced to the level where oil pressure times the effective area of the piston equals the flyweight and spring force, the propeller will stay at a balanced condition.

METERED PRESSURE LOW



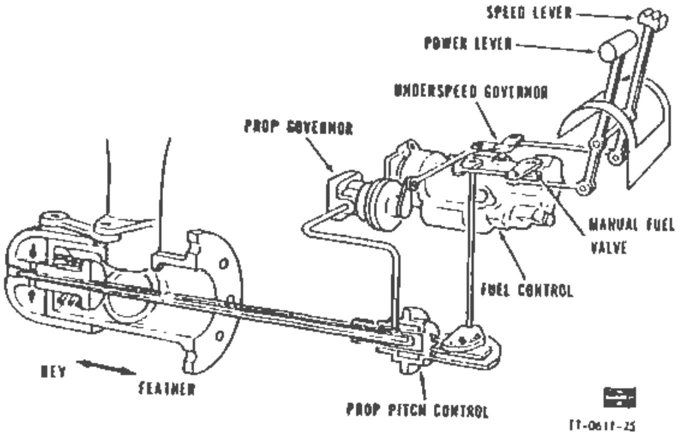
#154

Assume that the power lever has been moved forward. Due to the mechanical linkage between the power lever and the cam, the cam will rotate and move the follower sleeve to the right. This action uncovers the holes in the beta tube--as illustrated here--and the oil pressure in the propeller piston area drains into the case through the uncovered port in the beta tube. Loss of that oil pressure allows the heavy springs and the flyweights to move the propeller piston to a retracted position, towards the right. This, in turn, takes the blades toward a positive blade angle.

The propeller will continue to move until the holes in the beta tube line up with the follower sleeve seal bushing in the propeller pitch control. And again, the oil will be metered to just the right amount to hold the propeller in the selected position.

It is now easy to see why the propeller pitch control can be referred to as a "Variable Low Pitch Stop." By positioning the power lever between flight idle and reverse, the pilot can increase or decrease the length of the follower sleeve. Wherever the follower sleeve is put, the propeller will seek a balanced position hydraulically.

POWER MANAGEMENT LINKAGE



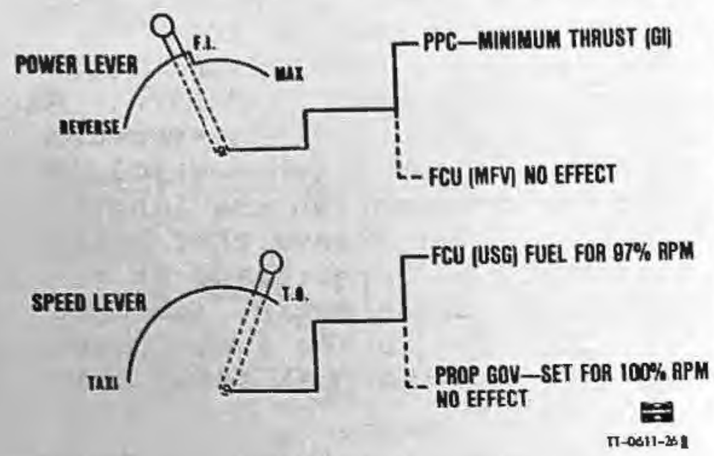
#156

This illustration shows the power lever mechanical connection to a shaft on the fuel control that has been identified in this drawing as the "Manual Fuel Valve." Linkage also connects this shaft to the propeller pitch control.

This linkage from the power lever is connected first to the propeller pitch control in many installations. Operation is the same in either case.

The speed lever is mechanically connected to the underspeed governor shaft on the fuel control and through linkage to the propeller governor.

BEFORE TAKEOFF - BETA MODE



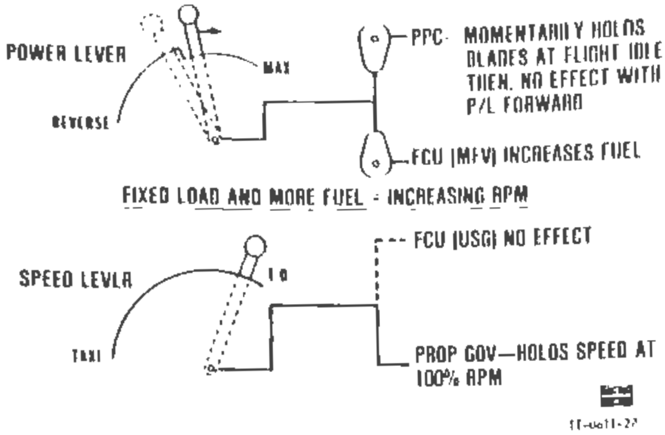
#157

Let's review again what happens in the transition from beta mode to propeller governing mode during takeoff. In this picture, the cockpit control lever positions indicate that the aircraft is sitting at the end of the runway ready for takeoff. The power lever is at ground idle position and the solid line drawn here identifies that the propeller pitch control maintains a minimum thrust propeller blade angle. During this phase of operation, the power lever connection to the manual fuel valve (MFV) has no effect, since the MFV is asking for less fuel than we actually need.

The speed lever, at the high rpm position, provides the necessary fuel to run the engine at 97 per cent rpm, as indicated by the solid line. The speed lever accomplishes this through the action of the underspeed governor in the fuel control. That portion of the speed lever linkage that is connected to the propeller governor has set the spring in the governor representing 100 per cent rpm.

It is important to recognize at this point, that the propeller governor would sense an underspeed condition since it has been calibrated to hold 100 per cent, but the engine only has fuel enough to run at 97 per cent. It is necessary for the propeller governor to sense underspeed in order to be in beta mode.

TAKEOFF - PROP GOVERNING MODE

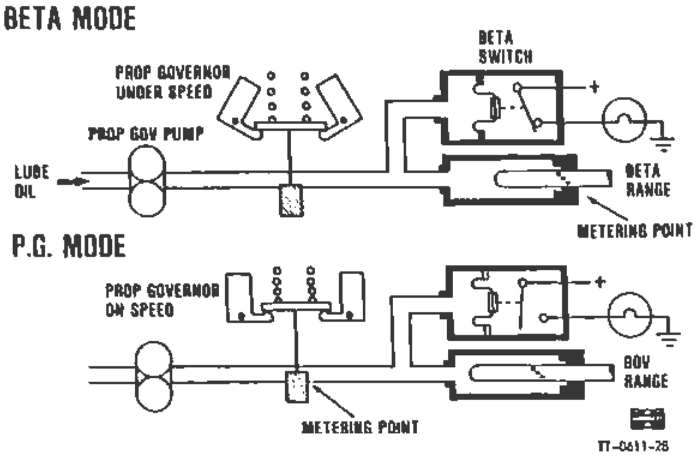


#158

As the pilot moves the power lever forward for takeoff, the mechanical linkage to the cams in the propeller pitch control and fuel control causes them to rotate. At the flight idle position, the cam in the propeller pitch control is designed to establish the length of the follower sleeve that will momentarily hold the blade at a flight idle blade angle. At that point, the cam in the fuel control will increase the fuel being sent to the engine.

You will recognize from your study of the constant speed engine concept that holding the load at a fixed point and applying more fuel develops more power and results in increasing rpm. As the rpm increases from 97 per cent, it approaches the propeller governor setting of 100 per cent. When the propeller governor senses that the engine is at 100 per cent rpm, the propeller governor will then meter oil pressure to the propeller. It is at this point that the change from beta mode of operation to propeller governing mode of operation occurs. From this point on, the propeller pitch control and beta tube serve no other useful function than to provide a means to get the propeller governor metered oil in and out of the propeller. The underspeed governor in the fuel control now has no effect, since the fuel is now being controlled by the power lever positioning of the fuel control.

METERED PROP OIL CONTROL



#159

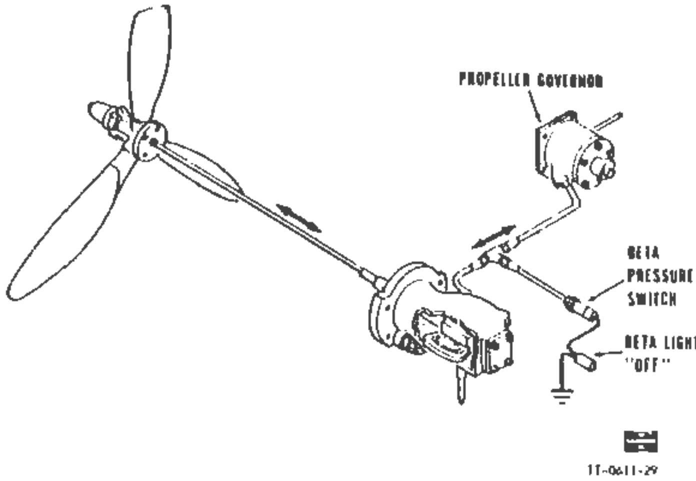
There are two devices that can control the metered oil pressure to the propeller: the propeller governor and the propeller pitch control.

In the top drawing, which illustrates beta mode of operation, you can see that it is necessary that the propeller governor sense an underspeed condition. This will cause the governor to open wide and allow the high oil pressure to be felt at the propeller pitch control, where it will be metered to the propeller.

To make it easier for the pilot to know this beta condition exists, that high oil pressure is felt by the beta switch and turns the beta light on. This indicates that the pilot has control over the propeller blade angle by movement of the power lever.

In the propeller governing mode condition, we see that the propeller governor now senses an on speed condition and has positioned its metering valve to reduce the pressure to the propeller. This results in a higher blade angle position. Since the beta tube is attached to the piston, it will push the holes in the beta tube inside of the follower sleeve and from this point on, the propeller pitch control's only purpose is to get oil in and out of the propeller. It has no effect on the blade angle. Since the propeller governor metering is upstream of the beta switch, the beta light will be turned off. This signals the point of transition from beta mode to propeller governing mode.

PROP GOVERNING MODE

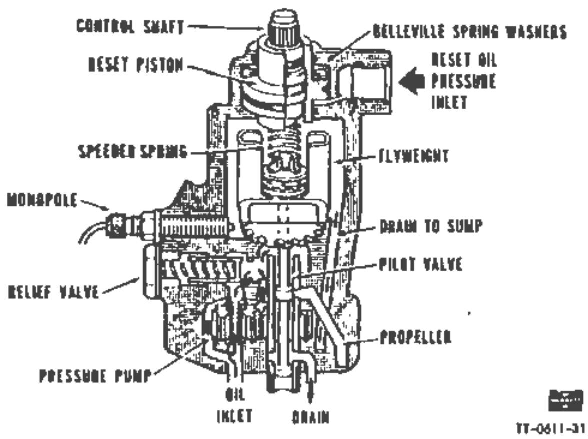


#160

In propeller governing mode, the propeller governor is controlling, or metering, the oil pressure to maintain just the right amount of oil in the propeller to cause the blade angle to load the engine and hold it at the rpm selected. The propeller pitch control in this case acts as nothing more than part of the plumbing. It furnishes a way to get the oil in and out of the propeller.

The beta switch located between the propeller governor and propeller pitch control would be sensing a low oil pressure under these conditions. The beta switch would be open and the beta light would be off.

PROPELLER GOVERNOR



#162

All models of the TPE331 Engine utilize a propeller governor purchased from the Woodward Company and--although the engine maintenance manual deals only with the removal, installation, and adjustment of this control--it is necessary to review the basic operation of the propeller governor at this point. This knowledge will arm the mechanic with the background to troubleshoot effectively and take appropriate corrective action.

The Woodward propeller governor utilizes a standard flyweight, spring and metering valve operation. The control shaft on the top of the governor is connected to the speed lever. In response to speed lever movement, the speeder spring will be adjusted. Since the main shaft of the governor is attached to, and driven by, the engine accessory section, engine rotation will result in rotation of the governor flyweights.

As the speed increases, centrifugal action causes these flyweights to move out, opposing the force of the speeder spring. When the flyweight force and speeder spring force are balanced, it will result in the positioning of a metering valve to limit the correct amount of oil pressure to the propeller to hold that rpm.

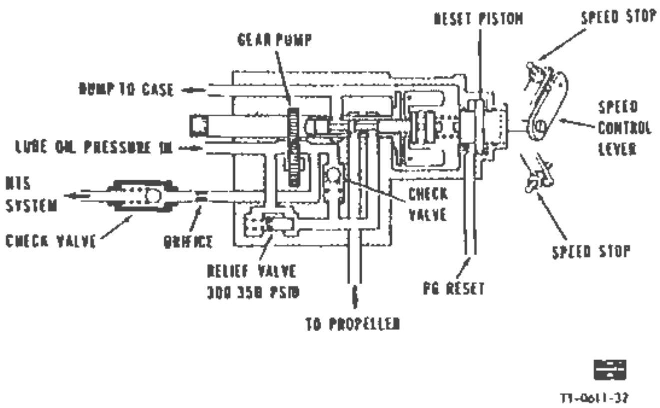
In the base portion of the governor, you can see that the same drive shaft will drive a two gear, spur gear, high pressure pump. This pump accepts lubrication oil from the engine and pressurizes it to a value limited by the relief valve. This value is typically 300 to 350 pounds above the lube pressure felt at the inlet.

Just above the relief valve a monopole can be seen. The monopole is a permanent magnet that counts the teeth of a very special gear, passing near to it. This gives a speed signal to the control system functions in the computer and to propeller sync systems.

At the top of the Woodward propeller governor, you will notice a special device called a "Reset Piston." Notice that the control shaft has a set of coarse threads which will cause an increase or decrease in speeder spring value as the control shaft is turned. Surrounding those threads is a reset piston mechanism that has some heavy belleville spring washers trying to push down to add to the speeder spring value. At the upper right hand side is a port for high oil pressure that will push the reset piston up, compressing the belleville spring washers. It is at this position that normal governor operation is maintained.

Under certain conditions, it is desirable to recalibrate the propeller governor above the 100 per cent that it normally operates at. Under those conditions, if the reset oil pressure is eliminated, the piston is then moved down by the strength of the belleville spring washers, thus adding to the spring force of the speeder spring and effectively calibrating the propeller governor to approximately 105 per cent.

PROP GOVERNOR SCHEMATIC



#163

This schematic of the propeller governor can be used to review the flow of oil through the governor. Note, on the left side, the entry of lubrication oil pressure into the inlet side of the spur gear type, high pressure pump. Discharge of that pump is felt on the top side of the check valve, opening that check valve and proceeding downward to the right side of the relief valve. If the relief valve setting is exceeded, the relief valve moves to the left and bypasses the excess oil back to the inlet side of the pump. That regulated oil is then available to go up to the metering valve. At the present time, the metering valve is positioned to meter the oil at that point. As the flyweights and spring forces may move the metering valve to the left, it would allow more of that oil to pass through the metering valve to the propeller.

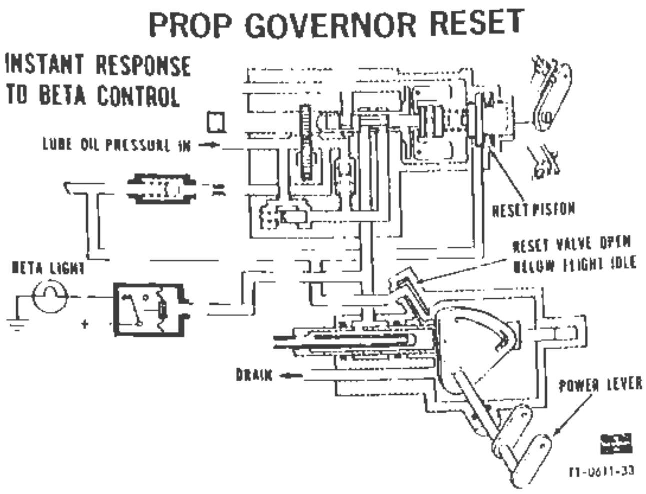
Notice the drain line at the top of the schematic that will allow that oil that is in the flyweight section to drain to the case. When the governor senses overspeed and the flyweight has moved out, moving the pilot valve to the right will allow the oil in the propeller to reverse flow back through that drain line into the case.

Of course, removing oil pressure from the propeller would cause it to take a higher blade angle.

On the right side of the schematic, minimum and maximum speed stop adjustment screws can be seen. The high speed stop is set at 100 per cent rpm, and the low speed stop would be set at approximately 95 per cent rpm.

Also visible is the oil pressure coming into the propeller governor reset piston area. The check valve, located in the center of the schematic, is normally open under propeller governor operation. It is located in that position to close and prevent loss of oil through the drain lines when the oil pressure is being provided to the propeller by the unfeathering pump. Later schematics will show this application.

The final item to notice in this schematic of the propeller governor is the source of high pressure oil going to the NTS system. That high oil pressure is from the propeller governor pump out of the base of the governor, through a flow limiting orifice and a check valve. The NTS, or negative torque sensing system, will be explained in later pictures.



#164

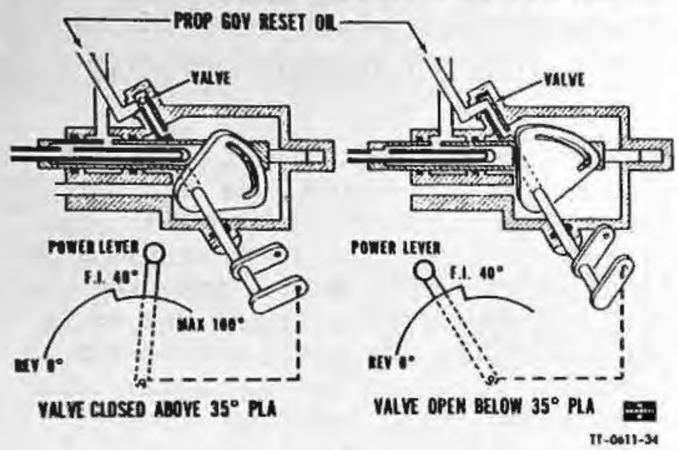
You have already learned that in order to have beta control of the propeller by the propeller pitch control, the propeller governor must sense an underspeed condition and open its pilot valve to allow the high pressure oil to be made available to the propeller pitch control. That high pressure turned on the beta light to indicate that the pilot now has control of the propeller by movement of the power lever.

This governor reset system is designed to create an instant response to beta control. This is particularly important during the landing phase of operation. As the aircraft nears touchdown, the pilot has retarded the power lever to the flight idle position. As soon as his wheels are on the ground, the pilot now desires to take control of the propeller, causing reverse blade angle as necessary, to brake the aircraft. As he brings the power lever back of flight idle, he wishes to recalibrate the propeller governor much higher than its normal 100 per cent to ensure that the propeller governor will sense an underspeed condition and give immediate control to the propeller pitch control. This is done by the reset system.

When the power lever is moved to the position in back of flight idle, it will rotate the shaft in the propeller pitch control. At the top end of that shaft is a valve. This valve has been closed during propeller governor operation allowing high pressure to keep the reset piston compressed, so that the propeller governor senses only the speeder spring value as adjusted by the speed lever.

As the pilot brings the power lever back of the flight idle stop, he opens that valve in the propeller pitch control, and the oil pressure that's been on the reset piston is allowed to drain into the case, through the propeller pitch control. As the oil pressure is removed, the heavy belleville springs add their force to the speeder spring and recalibrate the propeller governor to about 105 per cent. This ensures an instant response to beta at this very critical period of aircraft operation.

PROP GOVERNOR RESET VALVE



#165

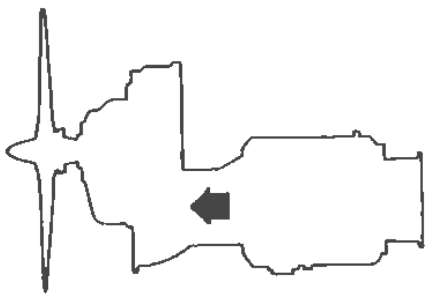
The picture of the propeller pitch control on the left side shows the connection of the power lever to the cam operating mechanism. Notice that we have talked previously about position of the power lever with the names "Full Reverse," "Flight Idle" and "Maximum." These positions can be related to degrees of power lever angle.

The pitch control has a protractor mounted with a pointer on its shaft. When the power lever is in the full forward maximum position, that pointer will indicate 100° on the protractor. The flight idle position is 40° and in full reverse, the pointer will indicate zero degrees.

It can be seen on the drawing on the left that the power lever presently is positioned somewhere between flight idle and maximum. This is the normal flight position. At this time, the valve on the end of the shaft on the propeller pitch control is closed and the high oil pressures are available to the propeller governor reset system.

The picture on the right shows that upon landing, the power lever has been brought back of flight idle. The system is rigged so that as the power lever is moved below 35° power lever angle, the shaft will be rotated to the point where the reset valve will be opened and the oil from the propeller governor reset piston will be allowed to drain into the case through the propeller pitch control. The points to remember here are as follows. Whenever the power lever is at flight idle or forward, that valve is closed. When the power lever is brought back of flight idle, and past the 35° power lever angle, that valve in the propeller pitch control is open.

POSITIVE TORQUE



ENGINE POWER IS DRIVING THE GEAR BOX AND PROPELLER

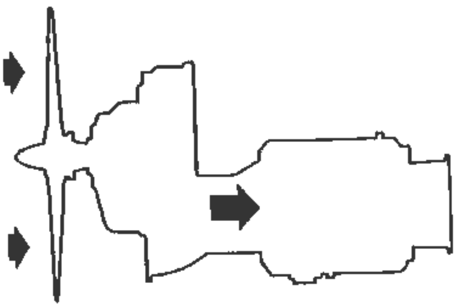
TI-0611-35

#166

It is important in multi-engine aircraft to protect the aircraft from asymmetrical thrust, in the event that one engine should quit in flight. Excessive drag on the side of the dead engine can make the aircraft very difficult to handle. You may be familiar with auto feathering systems used in some aircraft. The 331 Powered Aircraft does not use an automatic feathering system, but rather a system defined as "Negative Torque System Protection."

In order to understand negative torque, let's first consider what positive torque is. This picture identifies that engine power is driving the gearbox and propeller. This is positive torque and this is a normal condition.

NEGATIVE TORQUE



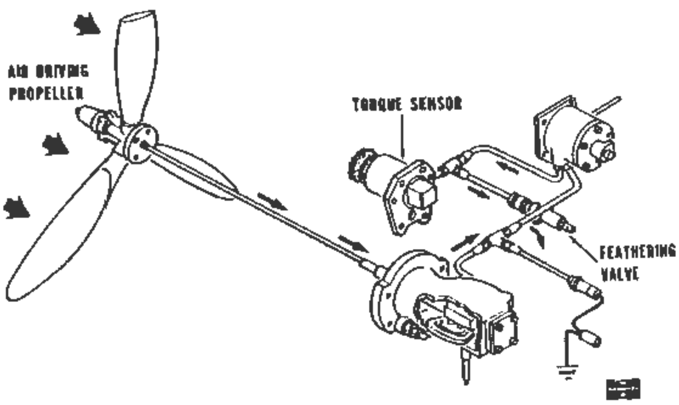
WINDMILLING PROPELLER AND GEARBOX ARE DRIVING THE ENGINE POWER SECTION

TT-0611-36

#167

Since positive torque is when the engine is driving the propeller, then negative torque must be when the propeller is driving the engine. This can occur if the flame were to go out in the power section. The speed of the aircraft would cause the airflow across the propeller to windmill the propeller, thus, driving the dead engine. This could cause a tremendous drag, resulting in asymmetrical thrust and a difficult aircraft to handle under these conditions. The NTS system, or negative torque system, is designed to automatically take care of this situation without any action on the part of the pilot.

NEGATIVE TORQUE APPLIED



TT-0611-37

#168

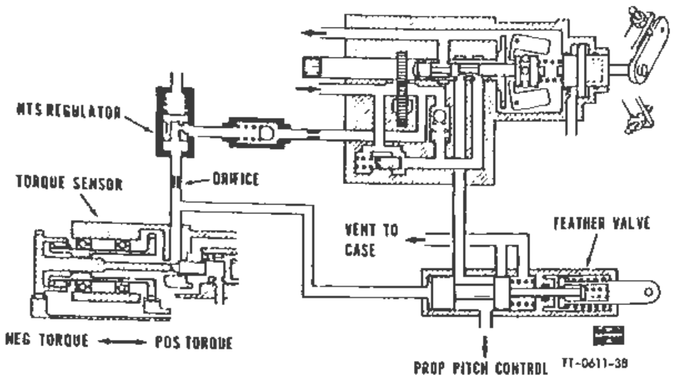
This drawing introduces a new component into the propeller control system. It is identified as the "Torque Sensor." The torque sensor is a mechanical device in the gearbox that can sense and measure either positive or negative torque. This device will be discussed in greater detail in the Torque Indication System section.

It can be seen from this picture that the torque sensor is connected to the oil control system for the propeller. It receives a high oil pressure signal from the propeller governor pump. That oil pressure signal can be sent to the feather valve under appropriate conditions of negative torque causing the feather valve to actuate and open passages that will allow oil pressure in the propeller to come back through the beta tube, propeller pitch control, and drain into the case at the feather valve. Obviously, if the oil pressure in the propeller piston area is reduced, the propeller moves toward the feathered position.

This reduces the negative torque and the drag that is felt by the aircraft. If the propeller were allowed to go to full feathered position, then this system could be described as an automatic feathering system.

NTS SYSTEM

- AUTOMATIC DRAG REDUCTION – PROP WILL CYCLE TOWARDS FEATHER
- DO NOT ALLOW NTS RPM IN CRITICAL RANGE



#169

The NTS system on the 331 Engine is not an automatic feathering system. The decision to feather the engine rests with the pilot. The NTS system is an automatic drag reduction system that will automatically reduce the drag created by a propeller on a dead engine. Let's examine the component on the left, identified as a torque sensor.

On the right end of the shaft we see a pilot valve that will move back and forth, depending upon the torque being sensed by this device. The arrows below the torque sensor indicated that the pilot valve would move toward the right when positive torque is being felt, and would move towards the left as a result of sensing negative torque.

When the pilot valve moves to the left, and restricts the flow of oil out of that system, the pressure at the end of the feather valve will build up rapidly. That pressure will cause the internal mechanism of the feather valve to move to the right, shutting off the oil coming from the propeller governor and allowing the oil that's in the propeller to drain back through the feather valve and vent to the case of the engine. Removing the oil from the propeller would start the blades towards the feathered position.

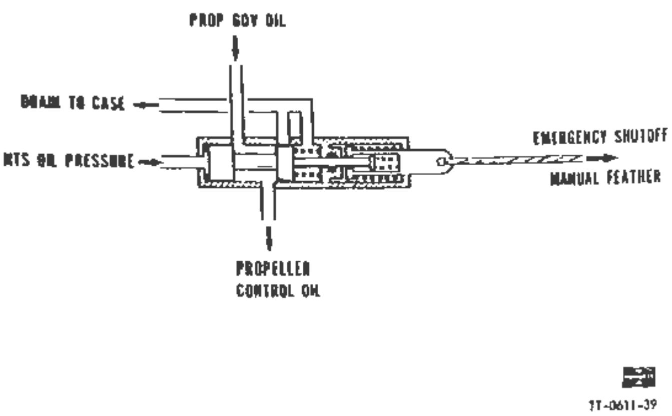
As the propeller blades were streamlining into the air, the torque sensor would sense less negative torque and move the pilot valve back towards the right position. Uncovering the port allows the oil being felt at the end of the feather valve to drain into the case. The feather valve is spring loaded to reseat, allowing the oil from the governor to go to the propeller and start driving the propeller back towards the lower blade angle. As the propeller blade angle moves toward the lower pitch position, the torque sensor again would sense an increase in negative torque and the cycle would be repeated.

This repeated cycle of propeller blades moving back and forth is referred to as "NTSing." The resulting drag from this propeller action is very low, allowing the pilot to maintain complete safe control over the aircraft. This automatic action allows the pilot time to make such decisions as: making sure that he recognizes which engine has the problem and making the decision as to whether to restart the engine or feather the propeller and continue on single engine.

You will recall during the start cycle procedure, that we cautioned against the engine staying in a speed range referred to as the "Critical Frequency." You may remember that the numbers were 18 per cent to 28 per cent rpm. If the engine is allowed to remain at that range of speed, vibration will become excessive and damage to the engine may occur. There are only two periods of engine operation when this is a concern: during the start cycle procedure and in the NTS operation.

The Pilot's Flight Operating Handbook will warn that, as the engine speed decays in a NTSing procedure, the pilot must not allow the engine to decay to an rpm in the critical range. The pilot must move the emergency control to feather the propeller as 30% rpm is reached.

FEATHER VALVE



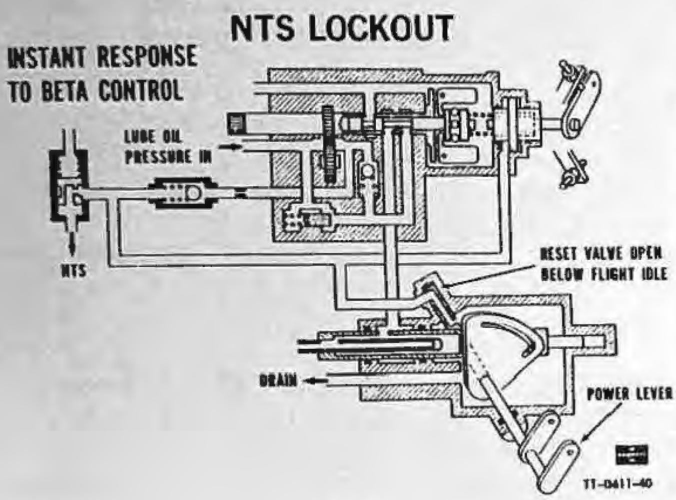
#170

It can be seen on this schematic that the internal piston assembly on the feather valve can be actuated by the NTS oil pressure coming in on the left side. This oil pressure will cause the piston in the feather valve to be moved to the right, blocking the oil from the governor. At the same time, it vents the oil that is in the propeller back through that portion of the feather valve that is aligned to the case drain, allowing the oil to drain out of the propeller into the case.

As described before, this system would repeat itself, and would be cyclic in nature, causing the NTSing operation. If the pilot sees that the engine is going to stop its rpm reduction in the 18 to 28 per cent range--or he has decided to feather the propeller--he will now move the emergency shutoff lever in the cockpit to the emergency shutoff position. It will shut off the fuel and also stroke the feather valve mechanically to the right position allowing the oil to be vented from the propeller.

In some aircraft, this emergency shutoff lever is used in conjunction with the speed lever.

It is in those aircraft where the speed lever is most commonly called a "Condition Lever," because it not only deals in the rpm selection of the engine, but also handles the emergency shutoff function. Other aircraft may have a separate control that is linked only to the emergency shutoff operation.



#171

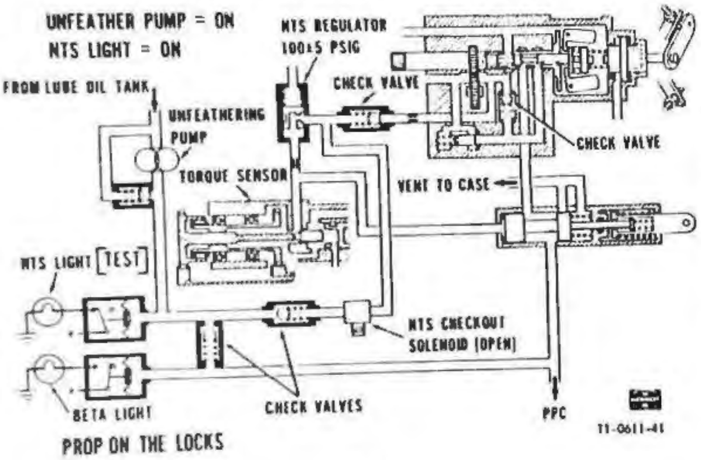
In some of the newer aircraft, an interesting situation has developed with regard to the NTS system. This is primarily due to heavier and larger propellers. As the aircraft is landing, the pilot will pull the power lever back to reduce the power and go into beta mode of operation. The bigger and heavier propellers tend to overrun, much like a flywheel. It is at that instant where a situation of negative torque could occur. Again, negative torque is when the engine is being driven by the propeller. This obviously is not desirable at this point in landing. The pilot does not want a propeller to NTS and reduce drag. He wants to take control of the propeller and deliberately create drag to brake the aircraft. Your engine includes a system to lock out the NTS system during this reverse action.

Notice on this drawing that the high pressure pump oil pressure from the governor to the torque sensor applies that oil also to the end of the same valve in the propeller pitch control where the oil pressure from the propeller governor reset system is controlled. As the power lever is positioned at flight idle or forward, that valve would be closed, and oil pressure would be normal on the propeller governor reset piston and in the NTS system.

As the pilot moves the power lever from flight idle back towards reverse and passes the 35° power lever angle point, the valve in the propeller pitch control is opened and the oil pressure is removed from the propeller governor reset system and the NTS system. Now there is no oil pressure in the system to cause the NTS action, thus, we have an instant response to beta control, even in the case of the bigger and heavier propellers.

In the maintenance actions described later in this section, you will be shown a very simple procedure for checking the proper operation of this propeller governor and NTS lockout system on the ground.

NTS GROUND CHECK



#172

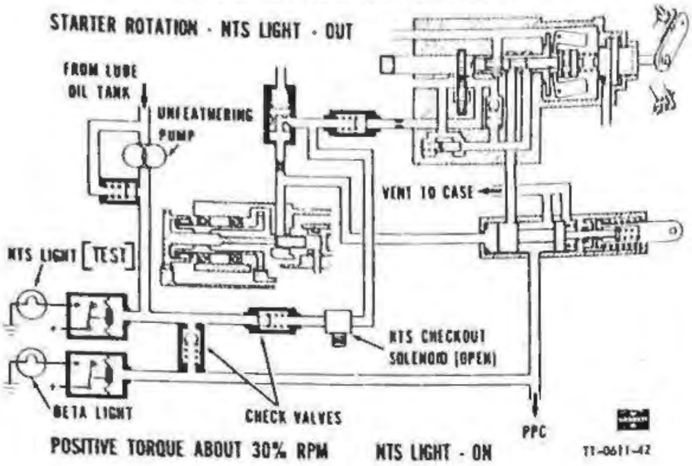
A ground check of the NTS system can be accomplished by utilizing the components identified in this system. The source of oil pressure will now be the unfeathering pump. Notice on the left side of the drawing, there is an NTS test light in addition to the beta light. Below the torque sensor, you see a NTS checkout solenoid that will be opened by a switch on the cockpit panel during this ground check.

So far we have discussed negative torque with regard to the propeller being driven by a windmilling action. It is also true that negative torque is created to the torque sensor when the engine starter is activated and the gearbox is driving the power section. During a start sequence, with the propeller still on the locks, this negative torque created by the starter can be used to check out the negative torque sensing system.

The pilot turns the switch on the panel to the position opening the NTS checkout solenoid and then turns on the unfeathering pump. You can then follow the path of oil pressure being provided by the unfeathering pump. This oil pressure to the propeller will have no effect on the propeller since the power lever is positioned forward of ground idle for a start position. The importance of this particular pressure is its effect on the NTS switch, which is set generally for approximately 100 pounds. So the oil pressure from the unfeathering pump, in addition to filling the lines to the feather valve and the NTS system, will also provide the pressure to turn the NTS light on.

In this particular mode of operation, the torque sensor pilot valve is moved to the right so there is no pressure on the end of the feather valve since that oil is leaking into the case in the torque sensor. To review, with the propeller on the locks ready to start the engine, with the unfeathering pump on, and the NTS check valve solenoid open, that pressure will turn on the NTS indicator light in the cockpit. We are now ready for the next step.

NTS GROUND CHECK



#173

With the oil pressure conditions of the unfeathering pump now established, we are ready to begin an engine start procedure. It will be important to observe the action of the NTS check light during this procedure. As the start switch is turned to the start position, the starter begins to crank the engine. The torque sensor will immediately sense a negative torque signal because the gearbox is trying to drive the power section. The pilot valve of the torque sensor will move to the left and restrict the oil from draining into the case. The NTS oil pressure will build up on the end of the feather valve and move it to the right as shown. This opens a path that the oil provided by the unfeathering pump can now drain through the feather valve into the case. That reduction in pressure caused by this large leak will cause the NTS light to go off. The fact that the NTS light did go off assures us that the feather valve has been actuated by the oil pressure from the torque sensor sensing the negative torque.

It is advisable to observe the NTS light during the rest of the acceleration. After 10 per cent, the engine lights off and will accelerate. Obviously, as the power section starts to drive the gearbox and propeller, the torque sensor will soon start to sense the positive torque. When it reaches that point--at about 30 per cent rpm--the torque sensor pilot valve will have moved to the right far enough to open the drain into the case. The oil pressure on the back of the feather valve drops, the spring reseats the feather valve, the pressure will again build in the system and the NTS light will come on.

Observing the light coming back on is assurance that the feather valve has reseated. At this point the unfeathering pump can be turned off and the NTS checkout solenoid switch can be turned off. At this point, the engine continues to accelerate on up to governed speed and procedures are continued as normal.

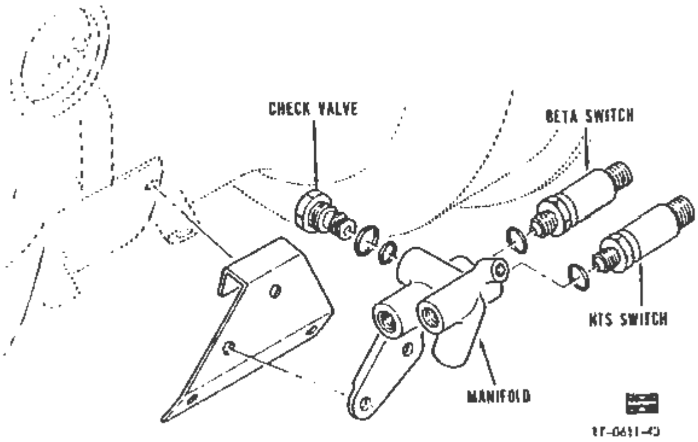
One of the important moments during this procedure was the point at which the NTS light went out when the starter was engaged, indicating correct action of the torque sensor and the unfeathering valve.

Secondly, it is important to observe that the NTS light came back on at about 30 per cent rpm to indicate that the feather valve was reseated in a normal manner. The Pilot's Operating Manual will also describe a procedure whereby a flight check of the NTS system can be accomplished and should be done if there has been major maintenance done on the engine that involves disassembly of the gearbox, including the torque sensor. The flight check will simply consist of turning off the fuel and seeing that the NTS system takes the propeller into an automatic NTSing operation.

There is one final item in this system that is worthy of note. The NTS checkout solenoid is used in those systems that have the propeller governor reset and NTS lockout system valve in the propeller pitch control. It can be seen that if we did not have a solenoid blocking that path, any attempt to put the propeller on the locks by using the unfeathering pump would be unsuccessful.

If this solenoid did not block the path, moving the power lever into full reverse would open the valve in the propeller pitch control and allow the unfeathering pump pressure to escape into the case and you would never get the propeller to go to reverse. Under normal operation, the NTS checkout solenoid valve is closed and it is used only for this type of ground test of the NTS system.

BETA/NTS SWITCH MANIFOLD



#174

This illustration shows the mounting provisions for the beta and NTS switch. The manifold housing is usually mounted near the fuel shutoff valve. There are two ports accepting the NTS and beta switch. Also included in the housing is the check valve that you have seen previously in the schematic. This check valve prevents loss of beta pressure normally supplied by the propeller governor pump, back through an inactive unfeathering pump. It is normally opened by the pressures from the unfeathering pump during the operation where the unfeathering pump is supplying the oil rather than the propeller governor. Other ports on the manifold provide a connecting point for the oil from the unfeathering pump, and the connection of a line to the propeller pitch control.

MAINTENANCE ACTIONS

	REFERENCE
• PROPELLER RIGGING ADJUST START LOCKS	A/C MM
• PROP PITCH CONTROL RIGGING PACKINGS PARTS WEAR	ENG MM
• PROP GOVERNOR STOP ADJUSTMENT RIGGING	ENG MM
• FEATHER VALVE RIGGING	A/C MM
• BETA-NTS SWITCHES	ENG MM
• NTS LOCKOUT CHECK	ENG MM

TT-0611-44

#175

It is important for the maintenance mechanic to understand those maintenance actions described in the official publications that can be accomplished in the propeller control system. With the propeller, some rigging and adjusting of start locks is involved. With the propeller pitch control, there is rigging, as well as, inspection of packing and parts. The engine maintenance manual will describe the stop adjustment procedure and rigging of the governor.

The feather valve also has a rigging procedure that will be found in the aircraft maintenance manual. The beta and NTS switches can be checked for proper calibration and the NTS lockout check can ensure satisfactory operation of the NTS lockout and propeller governor reset system.

PROP RIGGING

- ADJUST F.I. BLADE ANGLE
- CHECK INTERNAL STOP BLADE ANGLES AT FULL REVERSE AND FEATHER
- CHECK BLADE ANGLE ON THE START LOCKS

  CORRECT BLADE ANGLES FOR EACH AIRCRAFT WILL BE OBTAINED FROM THE AIRCRAFT FLIGHT/MAINTENANCE MANUALS

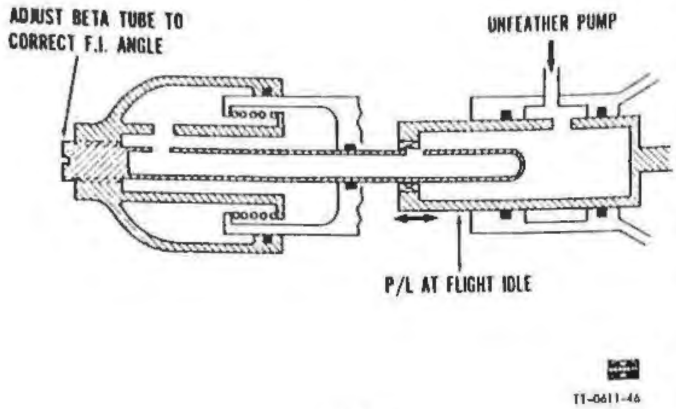
TT-0611-45

#176

It is recognized that internal propeller work will probably not be done by the engine mechanic. However, several operations are the responsibility of the engine mechanic. Adjusting a correct flight idle blade angle once the propeller has been installed matches the propeller to the engine. The engine mechanic may also check and correct the start lock positions, as necessary. Maintenance mechanics should certainly check the internal stop in the propeller in the full reverse and the feather position even though he may not be the one to take corrective action.

As we consider the engine mechanic's job of adjusting flight idle blade angle, or checking any of the other blade angles, it must be realized that those angles will be defined in the aircraft manuals.

FLIGHT IDLE ADJUSTMENT



#177

In order to ensure compatible operation of the propeller in response to the cockpit controls, the flight idle position is used to calibrate the two together. The adjustment of the flight idle blade angle with regard to the position of the power lever is done by adjusting the beta tube length at the threaded end at the propeller piston. This will adjust the dimension between the propeller piston and the follower sleeve in the propeller pitch control. Recognizing that as the piston moves out, the blade angle is decreased and as the piston is moved inward to the right, blade angle increases, it then stands to reason that by adjusting the dimension from the follower sleeve in the propeller pitch control to the piston, we can achieve a given blade angle. Utilizing the proper protractor measuring equipment to measure blade angles it will be necessary to provide oil pressure to the propeller with the unfeathering pump.

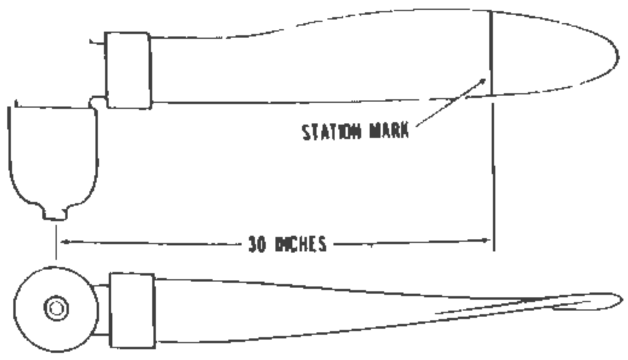
This procedure will be as follows: with the power lever at flight idle detent and the propeller off the locks, the unfeathering pump will be turned on, providing oil pressure into the propeller. This pressure causes the piston to move out until the metering point established by the holes in the beta tube and the follower sleeve will result in just the pressure necessary to balance spring force in the propeller. The blade angle will be measured at that point. Any adjustment necessary to obtain the correct blade angle will be made by turning the beta tube at the piston end.

Turning the beta tube clockwise will result in decreasing the blade angle. One complete turn of the beta tube will result in approximately two degrees change in the blade angle.

The aircraft maintenance manual will point out several cautions that must be observed. One will be the duty cycle limits of the unfeathering pump. Normally, this will be about 30 to 60 seconds "ON" and some period "OFF" for cooling the electric motor. Secondly, as the unfeathering pump is pumping oil into the system, it is lowering the supply in the engine oil tank. Obviously, the engine is not running, so the scavenge pumps are not returning the oil to the tank and the supply will be depleted. It will be necessary periodically during the adjustment procedure to return the oil from the case back into the tank. This may be accomplished by simply rotating the propeller in its normal direction of rotation by hand. When the flight idle blade angle has been adjusted to the correct value, the beta tube adjustment at the threaded end will then be locked in position by the use of a lock bolt.

Oil temperature affects viscosity and will cause errors in setting blade angle. Refer to the maintenance manual for guidance in compensating for oil viscosity effects.

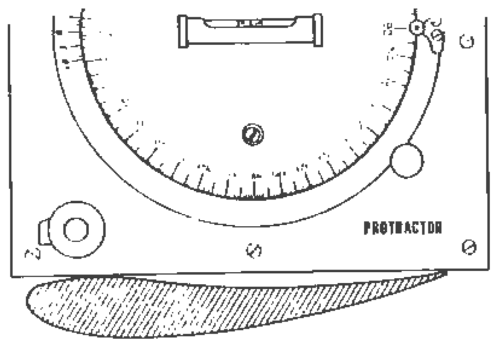
PROP BLADE TWIST



#178

All propeller blades have a twist. The angle is different at the tip end than it is as you proceed towards a hub. In order to measure blade angles, you must consistently measure those angles at the specified point. In practically all of the propellers used on the 331 Engine, this point will be 30 inches from the center of the propeller out towards the tip. It will be identified on the back side of the propeller blade by a paint stripe across the width of the blade. This is referred to as the "30 Inch Station."

BLADE CAMBER



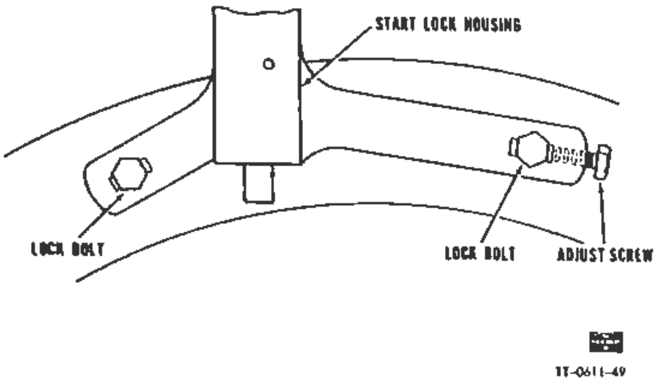
PROTRACTOR MUST EXTEND OVER LEADING AND TRAILING EDGES

#179

Not only must the measuring device for checking blade angles be used at the appropriate 30 inch station, it also must be used in a way to minimize the error caused by the camber of the back side of the blade.

This picture shows the protractor being used so that the wide edge is able to extend over the leading and trailing edges of the propeller blade so that consistency will be obtained in the readings. If the protractor is used improperly, it can make considerable difference in the readings taken from one blade to the next.

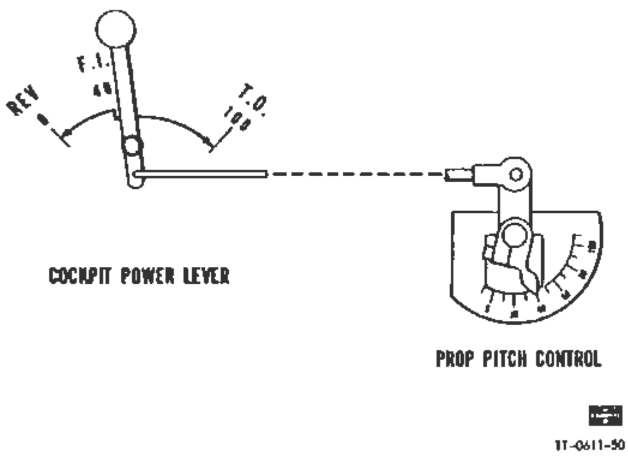
START LOCK ADJUSTMENT



#180

Positive blade angles of one or two degrees are usually specified by the Pilot's Operating Handbook for the blades when they are on the start locks. It is critical that these locks hold all blades within very close tolerance. If the blades were not of the same angle, this could cause excessive vibration during the start acceleration or any operation where the engine is running with the propeller still on the locks. The adjustment will be to move the housing containing the pin relative to the position of the plate that is a permanent part of the propeller blade.

PPC RIGGING



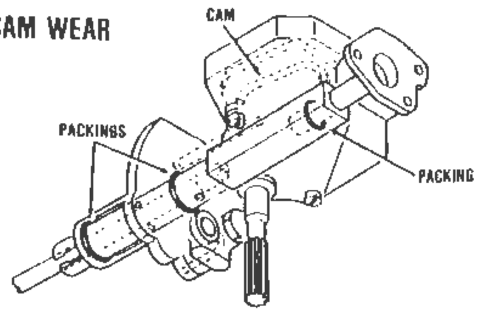
#181

At this point, it is appropriate to note the rigging of the propeller pitch control as part of the propeller control system discussed in this section. Reference has been made to the protractor attached to the propeller pitch control. This protractor is marked off in degrees from zero to 100. Note the degrees referred to in the picture of the power lever, telling us that when the power lever is at reverse, the protractor on the propeller pitch control should point to zero. When the power lever is at flight idle, the protractor should point at 40 degrees. And when the power lever is full forward, the protractor should point at 100 degrees. Establishing the flight idle blade angle as previously described, gave us the correspondence between the power lever at the flight idle detent and the propeller pitch control at the 40 degree position.

The remainder of the linkage from the aircraft system is responsible for the appropriate travel to the zero and to the 100 degree position.

PPC MAINTENANCE ITEMS

CAM WEAR



PACKING LEAKS

TT-0611-51

#182

The engine maintenance manual describes the proper disassembly and inspection procedures on the propeller pitch control. If the propeller pitch control is suspected of internal leakage, the three packings indicated here should be inspected. These packings normally prevent the leakage from the beta oil pressure into the drain area of the propeller pitch control. Another possible source of leakage is the bushing seal on the end of the follower sleeve.

The manual will also give the procedure for inspecting the cam and the cam follower. These parts may be replaced if wear above the limits specified in the manual is indicated.

BETA TUBE

REMOVE BETA TUBE FIRST AND INSTALL LAST WHEN REPLACING:

- PROPELLER
  ALWAYS REMOVE AND INSTALL HARTZELL PROPELLERS IN THE FEATHER POSITION
- PROP PITCH CONTROL
  TURN SHAFT TO 100° TO AID IN REMOVAL

HANDLE BETA TUBES WITH CARE!

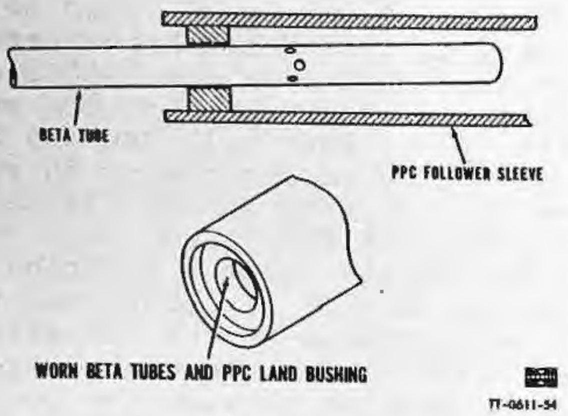
TT-0611-53

#184

Since the beta tube extends all the way from the propeller piston back through the gearbox, into the propeller pitch control, it is obvious that it would be very easy to damage the tube if any attempt were made to remove the propeller with the beta tube still installed. It must always be removed before attempting to take off a propeller or a propeller pitch control. Remember to put the propeller into feather before the beta tube is removed. The beta tube is attached to the propeller and rotates at high speed. It must be absolutely straight and the surface near the sealing areas must be true. Handle the beta tube with care.

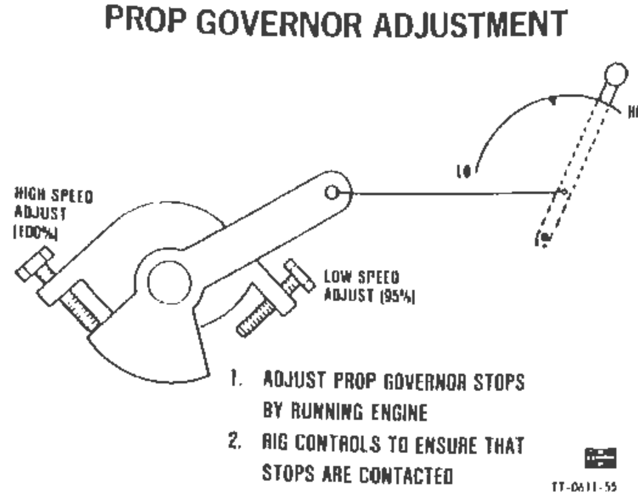
In attempting to remove the propeller pitch control, it is advisable to turn the propeller pitch control shaft to the maximum power, or 100 degrees, position. This will retract the follower sleeve and make it easier to remove the propeller pitch control from the accessory section.

BETA TUBE/PPC ALIGNMENT



#185

Since the beta tube rotates at high speed, and the propeller pitch control follower sleeve is stationary, it is important that they are properly aligned. When installing the propeller pitch control, mating surfaces must be cleaned, gaskets installed, and the proper torque applied to the attaching bolts. Beta tubes should also be examined to see that they are not bent or that there is no damage in the area contacting the land bushing in the propeller pitch control. Misalignment or damaged contact surfaces may be evident by either damage to the beta tube or to the bushing area in the follower sleeve. Inspection of this bushing is also described in the engine maintenance manual and it may be replaced if necessary.

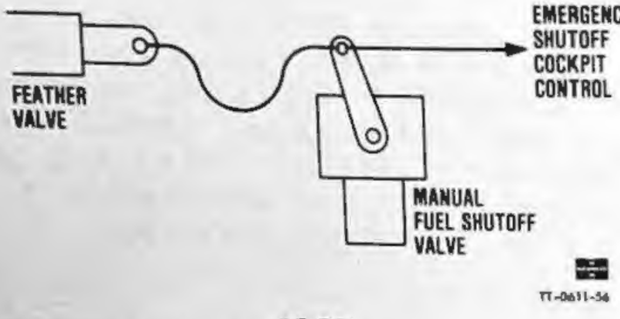


#186

The procedure for adjusting the high and low speed stops on the propeller governor is identified in the engine maintenance manual. This will involve running the engine and taking readings of engine speed to indicate where the stops are presently set. After shutting down the engine, the appropriate adjustment will be made to the low speed or high speed stops. Once the stops are set, it is extremely important that the rigging of the speed lever be done correctly to ensure hard contact to the stops. If the propeller governor lever does not contact the stops, this will usually be evident by inconsistency in running at the selected speed. As an example, if the speed lever were moved to the takeoff position asking for 100 per cent, and the rigging prevented the propeller governor lever from contacting the high speed stop, then the position of the governor lever would be determined by the rigging and not the stop.

FEATHER VALVE RIGGING

AIRCRAFT RIGGING PROCEDURES ENSURE FUEL SHUT OFF BEFORE STROKING THE FEATHER VALVE



. #187

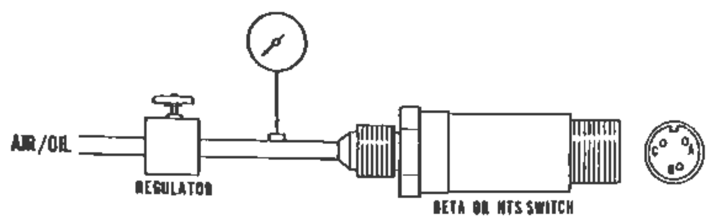
In order to manually stroke the feather valve to a position that will allow the propeller to fully feather, we must use the aircraft installed system. This system begins with an emergency shutoff cockpit control. This may be incorporated into the speed lever function in some airplanes and may be a separate control in others. When stopping the engine under emergency conditions, it is vitally important that the fuel supply be stopped before feathering the propeller.

Let's assume for a moment that this system was misrigged in such a way that the feather valve allowed the propeller to go to the feathered position before the fuel was shut off. Obviously, the extreme load of the feathered propeller would cause the rpm of the engine to decrease and the natural reaction of the fuel system would be to put more fuel into the engine. With an increasing load, decreasing rpm and more fuel, the temperatures would go extremely high very quickly with resulting damage to the turbine section. Consequently, the aircraft maintenance manual will be very specific in the rigging of this system.

The lever on the manual fuel shutoff valve must be activated to a point where the fuel has been shut off before you even start to move the feather valve. This rigging should be periodically checked on the ground while the engine is running. The emergency lever should be taken very slowly towards the shutoff position with one hand near the stop switch as a precaution.

As the lever approaches the shutoff position, a point should be reached where the fuel flow would drop to zero and the engine would flame out. Momentarily stopping the lever action at that point should indicate the propeller staying at essentially the same blade angle. Continued movement of the control lever should then stroke the feather valve and the propeller should immediately go to a full feathered position.

BETA/NTS SWITCH CHECK



	BETA	NTS
INCREASING PRESSURE	A & B CLOSE 310 - 320 PSI	A & B OPEN BEFORE 120 PSI
DECREASING PRESSURE	A & B OPEN WITHIN 50 PSI OF CLOSING PRESSURE	A & B CLOSE BEFORE 100 PSI

TT-0411-57

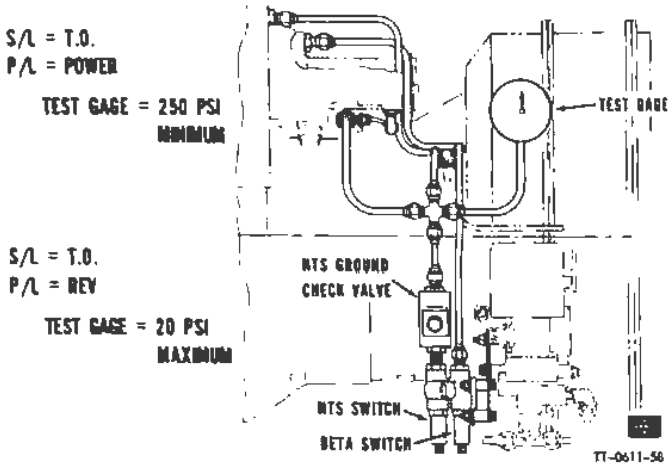
#188

A beta or NTS switch utilizes oil pressure acting against a diaphragm to actuate microswitches within the switch assembly. The electrical connector is typically a three pin plug as shown here. By appropriately connecting a continuity meter to the pins and applying a controlled source of pressure, the calibration can be checked as indicated.

On the beta switch, as the pressure is increased slowly, between 310 and 320 psi, continuity should be indicated between pins A and B, indicating that the switch circuit has been closed. As the pressure is slowly decreased, the pins A and B circuit should open within 50 pounds of the pressure that they closed at.

An NTS switch operates in the opposite direction, increasing pressure to the NTS switch. Circuits A and B should open before reaching 120 psi. On decreasing pressure, A and B circuits should close before decreasing to 100 psi. This procedure is covered in detail in the engine maintenance manual. Operating values may vary and the manual should be used to determine correct numbers for various part number switches.

NTS LOCKOUT/PROP GOVERNOR RESET



#189

You will recall earlier in this section, when the NTS lockout and propeller governor reset systems were discussed, that both of these systems depended upon the availability of oil pressure. During landing, when the pilot would bring the power lever back of flight idle and past the 35° point, the valve in the propeller pitch control would open, causing the oil in these two systems to be drained into the case through the propeller pitch control. The loss of that oil pressure would lock out the NTS function and would allow the propeller governor to be reset to 105 per cent.

This system can be checked very simply by installing a test gage as shown in this picture. As the engine is run with the speed lever at takeoff and the power lever forward of flight idle, this test gage should indicate a minimum of 250 psi oil pressure. Leaving the speed lever at takeoff rpm, and bringing the power lever back towards reverse, the test gage will drop showing no more than a 20 psi maximum oil pressure. This check assures correct oil pressures in the NTS lockout and propeller governor reset systems.

TYPICAL TROUBLESHOOTING

SAMPLE SYMPTOM = "PROP WON'T COME OFF THE LOCKS"

YOUR UNDERSTANDING OF THE SYSTEM LEADS YOU TO THESE LOGICAL CONCLUSIONS:

A. IT TAKES OIL PRESSURE TO MOVE PROP TOWARD REVERSE
B. PRESSURE SOURCES: PROP GOV PUMP/UNF PUMP
C. PRESSURE LIMITING MAY BE DUE TO RESTRICTIONS OR LEAKS
- VERIFY PROCEDURES AND RIGGING
- CHECK PRESSURES—TEST GAGE/BETA LIGHT
- R&R WITH REGARD TO COST OF MAINTENANCE

TT-0611-59

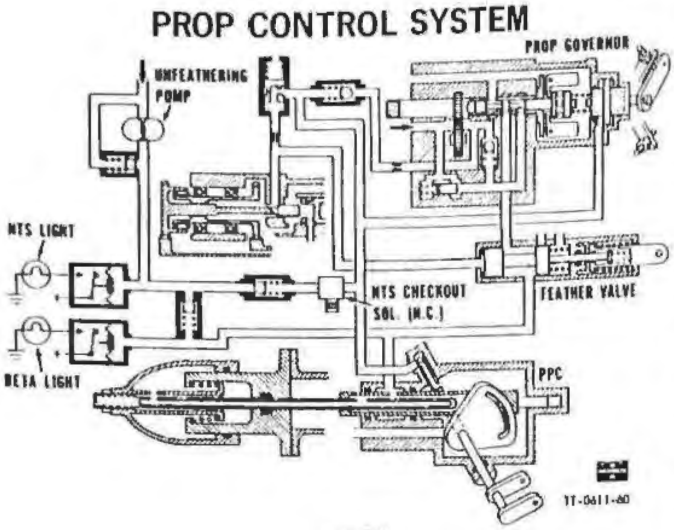
#190

A mechanic's ability to troubleshoot the propeller control system is largely dependent upon his understanding of that system and a logical thought process. Assume that the pilot's complaint is that he could not get the propeller to come off the locks. He claimed to have done everything properly, but the propeller would not move. Your approach to this problem would be influenced considerably by the use of the information and understanding that you now have.

First of all, you know that in order to make the propeller come off the locks, you must move the blades toward the reverse position and it takes oil pressure to the propeller to do that. Secondly, you recognize that oil pressure can be put to the propeller from two separate sources: from the propeller governor pump during engine running, and from an unfeathering pump when the engine is static. This is important because if you can make the propeller work with the unfeathering pump, but cannot make it operate with the propeller governor pump during operation, it is a clue that the problem may lie within the propeller governor and its pump, or possibly the check valve in the beta switch manifold may be stuck open. This would allow pressure from the unfeathering pump to act normally, but would cause a loss of propeller governor pump pressures during engine operation. Thirdly, the pressure limiting may be a restriction or it may be a leak. The experienced mechanic will attempt to isolate the cause of the problem in a manner that will result in the least expense and time.

It certainly would be easy to verify the procedures that the pilot said he used. Did he indeed move the power lever to full reverse in an attempt to get the propeller off the locks? When you move the power lever to reverse, does the rigging permit the propeller pitch control to respond properly? Also, pressure can be checked by installing a test gage at a port located on the propeller pitch control. This test gage and beta light are both pressure indicating devices. If the beta light comes on, there must be 300 pounds worth of pressure at that point.

Normally, with most propellers, you can expect the propeller to react if at least 150 pounds pressure is available. This may not be enough to turn on the beta light, but it should have operated the propeller. If the test gage indicates very low pressures, the system should be investigated for leaks or restrictions. In making a decision as to what components should be inspected or removed and replaced, it makes sense to do those things that cost the least time and money before involving yourself with more complex actions. It is certainly easier to remove a feather valve and to check it for possible leakage than it is to remove a propeller pitch control.



#191

This illustration combines all of the components discussed in this propeller control system section: the propeller governor with its pump relief valve, metering and check valves, and the propeller governor reset piston. Also shown are the feather valve, and below that, the propeller pitch control with its cam, follower sleeve, and drain valve. The light systems are included for the beta pressure and the NTS ground test, as well as the NTS checkout solenoid valve and check valves. The unfeathering pump is shown in the left hand corner and the torque sensor system is in the center. This illustration, or similar ones from the appropriate engine maintenance manuals, can provide valuable assistance to the mechanic in troubleshooting the system.

SUBJECT:
SECTION 6 - PROP CONTROLS

WORKBOOK EXERCISE 4

1. Available power, with the propeller in full reverse, is limited by:
   a. Torque limit red line.
   b. A propeller internal stop.
   c. Maximum turbine temperature.
   d. A or C, whichever comes first.

2. With the propeller pitch angle at full reverse and the aircraft on a landing roll at 80 knots, the angle of attack of the propeller would:
   a. Decrease as the aircraft forward speed dropped below 80 knots.
   b. Increase as the aircraft forward speed dropped below 80 knots.
   c. Remain the same as the aircraft forward speed dropped below 80 knots.

3. Decreasing metered oil pressure from the propeller governor to the propeller results in:
   a. Lower pitch angle with a tendency to reduce engine rpm.
   b. Lower pitch angle with a tendency to increase engine rpm.
   c. Higher pitch angle with a tendency to reduce engine rpm.
   d. Higher pitch angle with a tendency to increase engine rpm.

4. The power lever must be held in reverse during engine shutdown procedure to ensure start lock pin engagement until engine speed has dropped:
   a. To zero rpm.
   b. Below 25% rpm.
   c. Below 60% rpm.
   d. Below 73% rpm.

5. The beta light is turned off as the power lever is advanced for takeoff. This indicates that the:
   a. Prop governor is sensing an underspeed condition.
   b. Prop governor has taken control of metered oil pressure at 96% rpm.
   c. Prop pitch is now controlled by the prop pitch control.
   d. Prop governor has taken control of metered oil pressure at 100% rpm.

6. Engine rpm transition from 97% rpm in beta to 100% rpm in prop governing mode is a result of a momentary:

   a. Load reduction and fixed fuel flow causing rpm increase.
   b. Fixed load and increased fuel flow causing rpm decrease.
   c. Load increase and fixed fuel flow causing rpm increase.
   d. Fixed load and increased fuel flow causing rpm increase.

7. The power lever is moved aft of flight idle after the aircraft has landed on the runway. The prop governor reset system ensures instant response to beta control by:

   a. Increasing oil pressure available to the prop pitch control.
   b. Forcing the prop governor to sense an underspeed condition.
   c. Recalibrating the prop governor to an rpm not attainable due to insufficient fuel flow.
   d. All of the above.

8. Negative torque exists when the:

   a. Engine experiences a flameout.
   b. Engine is initially cranked by the starter motor.
   c. Power section is driven by a windmilling propeller.
   d. All of the above.

9. The TPE331 NTS system is:

   a. An automatic drag reduction system.
   b. An auto feathering system.
   c. An automatic power limiting system.
   d. A manual feather system.

10. The NTS system is locked out during beta operation on landing:

   a. Since no negative torque situation could be created after touchdown anyway.
   b. To prevent unnecessary loss of oil through the NTS system.
   c. To permit deliberate selection of a ground drag condition that may otherwise activate the NTS system.

WORKBOOK EXERCISE 4

11. The engine rpm can approach the critical frequency range of 18% to 28% rpm only during:

    a. Start/acceleration and full reverse.
    b. Start/acceleration and NTS.
    c. NTS and full reverse.
    d. Start/acceleration and low rpm taxi.

12. Which statement is true concerning flight idle blade angle adjustment?

    a. Blade angle is increased by turning the beta tube clockwise.
    b. Blade angle is decreased by turning the beta tube clockwise.
    c. Blade angle is decreased by turning the beta tube counterclockwise.

13. What effect would there be on engine operation if flight idle blade angle were adjusted with very cold oil?

    a. At a normal oil temperature, blade angle during prop governing mode would be low.
    b. Flight idle blade angle would be low with normal oil temperature.
    c. With normal oil temperature, flight idle blade angle would be high.
    d. Full reverse blade angle would be increased.

14. While putting the prop onto the start locks, unfeather pump output will not flow through the reset valve in the prop pitch control because of:

    a. The check valve located in the beta/NTS switch manifold.
    b. The check valve located between the unfeather pump and the reset valve.
    c. The closed NTS checkout solenoid.
    d. The valve being closed due to power lever position.

15. If the engine flamed out during flight, the NTS light:

    a. Will indicate NTS system operation.
    b. Will not operate due to the unfeathering pump being off.
    c. Will not operate because it is isolated from the prop control system by check valves.
    d. Both "b" and "c" are correct.

16. Pilot's statement: While in cruise with the speed lever set for 96% rpm, the right engine suddenly increased in rpm to 101%. The most likely cause would be:

a. The NTS orifice plugged.
b. The orifice between the prop governor and NTS pressure regulator plugged.
c. The feather valve leaking internally.
d. A very high leakage rate between the beta tube and the land bushing within follower sleeve.

17. Pitching the nose of the aircraft up would have what initial effect on the oil pressure at the prop pitch control?

a. Oil pressure would increase.
b. Oil pressure would decrease.
c. There would be no variation in oil pressure.

SECTION SEVEN:

FUEL SYSTEM

FUEL SYSTEM FUNCTION

THE FUEL SYSTEM MUST DELIVER FUEL TO THE ENGINE:

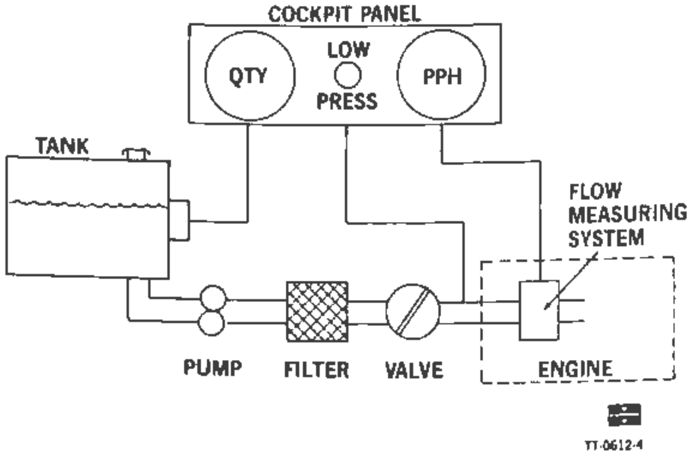
- IN THE RIGHT AMOUNT -
  - PUMPS
  - FUEL METERING CONTROL
  - DENSITY SENSORS
- IN THE RIGHT PLACE -
  - FLOW DIVIDER
  - MANIFOLDS
  - NOZZLES
- AT THE RIGHT TIME -
  - SHUTOFF VALVE
  - SPEED SWITCHES
  - AUTO/START COMPUTER

#195

In the Theory of Operation section, you learned that the variable power required by the engine in driving the propeller load is controlled by the amount of fuel that is delivered to the engine. This fuel represents the chemical energy that the engine will convert into useful power and heat. The Fuel System can be defined as being responsible for delivering fuel to the engine in the right amount, in the right place, and at the right time. Pumps, the fuel metering control, and density sensing devices provide the right AMOUNT of fuel. The flow divider, manifolds and the nozzles will deliver the right amount of fuel to the right PLACE. The shutoff valve, speed switches and the auto start computer ensure that the fuel is there at the right TIME.

In this section we will not only identify these components, but we will discuss them in sufficient detail to understand their operation. The ability to troubleshoot the fuel system and to take the necessary maintenance actions is dependent upon this understanding.

BASIC AIRCRAFT FUEL SYSTEM



#196

It is the responsibility of the aircraft fuel system to provide a clean, pressurized source of fuel flow to the engine under all operating conditions. Necessary filters, valves, and pumps are used in conjunction with cockpit instrumentation to identify that this requirement is being met.

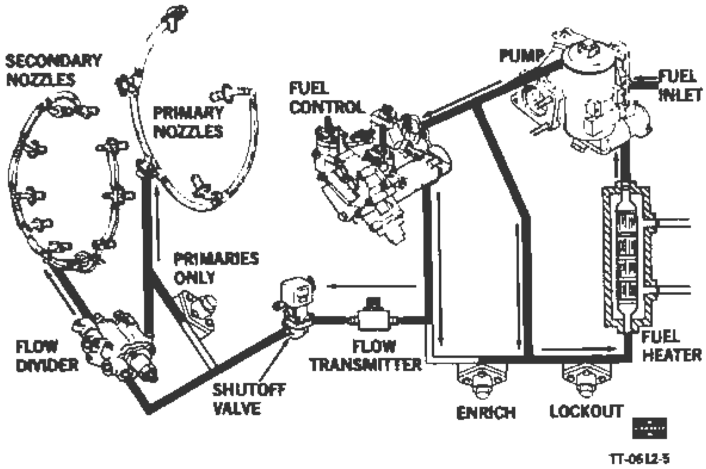
Typical aircraft cockpit instrumentation will include indications of quantity of fuel in the tank, the amount of fuel flowing to the engine, and some indication of satisfactory pressure at the inlet to the engine.

Some typical fuel sytem components and their functions are as follows. Fuel is taken from the tank by electrically driven boost pumps and is provided to a filter assembly to remove any foreign material. Typical firewall shutoff valves will allow the fuel to be shut off under emergency conditions. There is also a flow measuring system which consists of aircraft installed equipment, even though the flow measuring section is mounted in the plumbing of the engine, in most cases.

The typical aircraft instrument panel does not include a pressure gage to indicate metered fuel pressure. The important fuel gage is the flow indication in pounds per hour, which indicates the volume of fuel energy being put into this energy converting device. The low pressure indication can be either a low pressure warning light, or a gage, to indicate that the pressure at the inlet of the engine is maintained within the necessary limitations by the aircraft system.

The ability of the engine to operate with or without the boost pump in the aircraft system operating will be determined by the instructions in the Pilot's Operating Handbook.

ENGINE FUEL COMPONENTS



#197

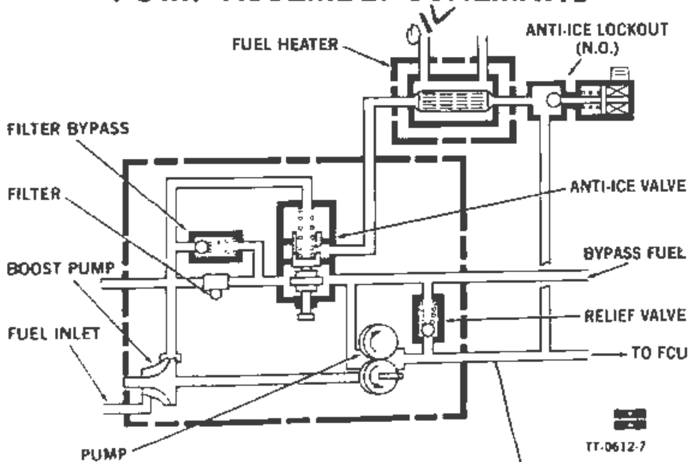
This simplified schematic of the engine fuel system can be used to identify the major components in that system. These components will be described in detail in this section.

You can see in the upper right hand corner that fuel from the aircraft system is provided to the engine at the "Pump Assembly." The engine driven pump boosts the fuel pressures required by the "Fuel Control," where the fuel is metered to provide the right amount to the engine under any given condition. Metered fuel flows through the "Flow Transmitter," which is part of the flowmeter indicating system, to a "Shutoff Valve" mounted on the engine. At the appropriate point in time, that shutoff valve will be opened allowing the fuel to flow to the "Flow Divider." The flow divider will divide the fuel so that the initial fuel will flow to the primary nozzle system for good starting and lightoff conditions. At the appropriate time during acceleration, the flow divider will add the capacity of the secondary manifold and nozzles so that the two manifolds together are capable of carrying the volume of fuel necessary to produce takeoff power. Next to the flow divider is a "Primaries Only Solenoid" that will be described later.

Alternate paths from the pump assembly are shown through the "Enrichment Solenoid," which will allow additional fuel to bypass the metering of the fuel control under certain starting conditions. That alternate path also permits fuel to flow through the lockout solenoid system through a "Fuel Heater" that will provide warm fuel to the inlet of the pump assembly to prevent filter icing. These major components will be discussed in this section in the normal sequence of flow, starting with the pump assembly.

The TPE331 Fuel Pump Assembly is mounted to the accessory section of the engine and is driven by the gear train in the gearcase. The opposite end of the fuel pump is a mounting pad for the fuel control. This pump assembly contains the engine driven boost pump, a filter assembly, a high pressure pump, a maximum pressure relief valve, and a filter anti-icing system.

PUMP ASSEMBLY SCHEMATIC



#199

Note on the left side of this drawing the shaft that drives two pumps: the boost pump on the left, and the high pressure pump on the right. The fuel inlet from the aircraft system is made available to the boost pump. Fuel from the boost pump proceeds up through the filter and the "Anti-Ice Valve" into the inlet of the high pressure pump. The discharge of the high pressure pump flows out to the fuel control to be metered for distribution to the engine.

Notice the test port above the boost pump. This is where many aircraft manufacturers will connect the low pressure warning light switch or gage.

The "Filter Bypass Valve," mounted above the filter, senses the differential pressure across the filter. Normally that pressure drop will be low enough so that the filter bypass will be closed and all of the fuel will go through the filter. If the filter becomes restricted above a value of about 13 psi differential, it will open the filter bypass and allow fuel to flow to the engine, even though it may be contaminated.

Most filter bypass valves have a red poppet that will be extended if the filter bypass is actuated. Part of preflight inspection would involve checking to see if that button is extended and, if so, to check the filter for possible indications of contamination.

Fuel from the filter is next supplied to the inlet of the high pressure pump. Since the high pressure pump is a positive displacement pump, it is capable of producing very high outlet pressures when the downstream flow is stopped by the shutoff valve. To protect the system from these excessive pressures, a "Maximum Pressure Relief Valve" is mounted parallel to the high pressure pump. When that pressure exceeds approximately 1100 pounds it will unseat the relief valve and allow the pump discharge to flow back into the pump inlet, thus protecting the system from pressures above that value.

Since filters are susceptible to collecting moisture that may result in ice and restriction, this system includes an automatic "Anti-Icing System."

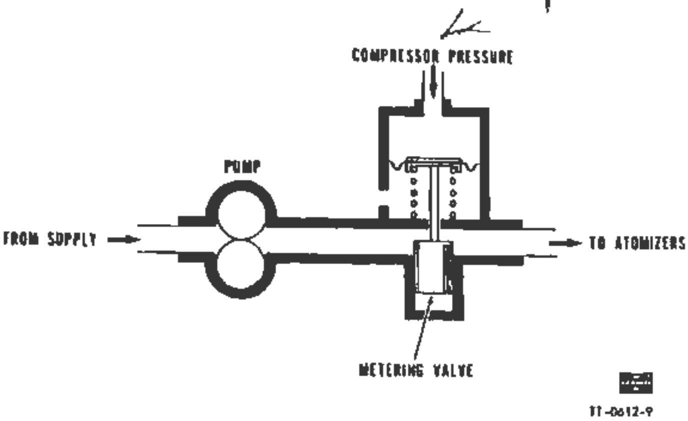
Notice that the fuel leaving the filter passes through the anti-ice valve, where it is sensed by a thermostatic sensing element. When the temperature of the fuel at this point gets below 40° Fahrenheit, the thermostatic element will route some of the fuel through a fuel heater. The fuel heater is a heat exchanger mounted in, or adjacent to, the oil supply tank. Fuel passing through the heater picks up the heat from the warm oil. This will maintain the temperature at the filter at a point higher than the freezing point of water. The system is completely automatic and requires no action by the operator.

Garrett 331 Engines may be purchased with a variety of fuel controls available. Some 331's use Bendix fuel controls. Other models have a Garrett control, and still others will utilize a Woodward fuel control. This decision is made primarily by the aircraft manufacturer. The 331 models covered in this book use a Woodward control.

The Woodward control is unique in that it is a mechanical device, rather than the traditional pressure ratio control used on many jet engines.

There is no intention in this book to delve into all of the details of the internal operation of the Woodward fuel control. The line maintenance mechanic can accomplish certain maintenance actions and adjustments. The internal details will be covered only to the extent that is needed by a mechanic for logical troubleshooting, and for recognizing when a problem is probably confined within the fuel control.

BASIC FUEL CONTROL

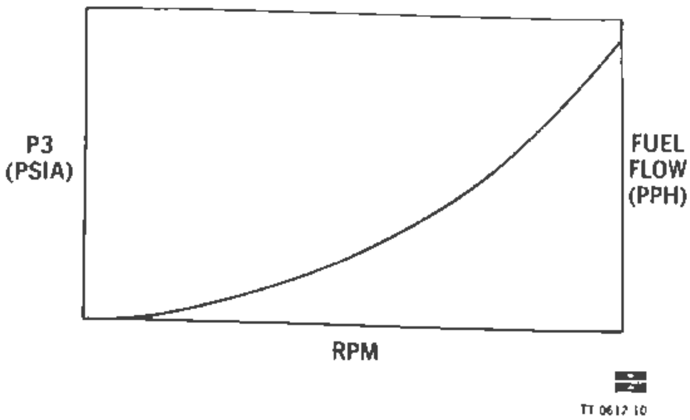


#201

You will recall that one of the functions of the fuel system is to provide the correct amount of fuel to the engine. It is the prime responsibility of the fuel control unit to accomplish this metering so that the right amount of fuel is delivered to the engine to meet all operating conditions. This schematic shows the high pressure pump in the fuel control supplying the pressure necessary to move a volume of fuel. The metering valve will regulate the amount of fuel continuing on to the atomizers in the combustion section.

Notice that the metering valve is connected to a spring loaded diaphragm. The spring force is attempting to move the metering valve upward, which would reduce the amount of fuel to the atomizers. As air pressure is allowed to build up in the chamber above the diaphragm, that pressure, times the effective area of the diaphragm, will create a force downward to oppose the spring and move the metering valve towards an open position. Since the logical source of air pressure will be compressor discharge, or P_3, we can then relate the amount of fuel compared to the amount of air.

FUEL/AIR VERSUS RPM

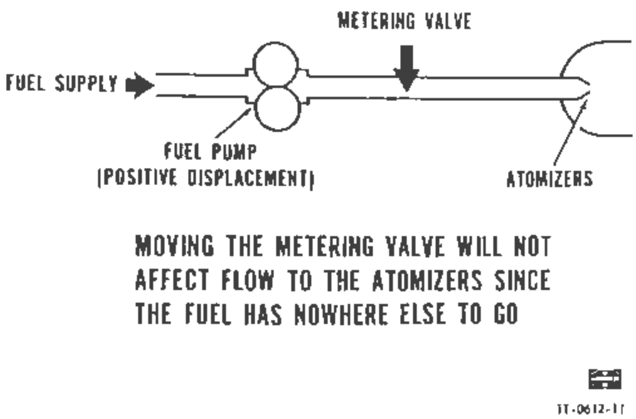


#202

This curve indicates the relative change in compressor discharge air pressures, or P_3, when compared to the speed of the engine in rpm. P_3 is indicated on the left side of the curve.

As the compressors increase in speed, the pressure of the air discharging from the compressor section would increase, as shown in this curve. As this increasing air pressure is applied to the diaphragm shown in the previous drawing, the metering valve would move towards an open position and increase the fuel flow proportionately. Fuel flow is indicated on the right side of this curve in pounds per hour.

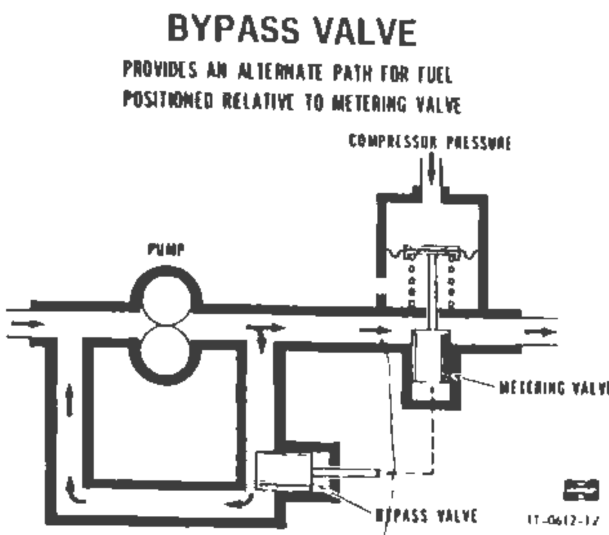
PUMP FLOW CONSTANT AT RPM



#203

In systems utilizing a fixed displacement fluid pump, the flow of fuel is a function of the cubic inch displacement per revolution, times the number of revolutions. For example, if the fuel pump had a displacement of one cubic inch per revolution and was rotated at one thousand rpm, the pump flow would equal 1,000 cubic inches. The pressure felt downstream of that pump would be a result of the resistance to that flow. If it were allowed to flow freely through a large opening, the pressure would be very low. If flow were restricted, as by a metering valve, the pressure would merely increase so that the same 1,000 cubic inches of fuel would continue to flow.

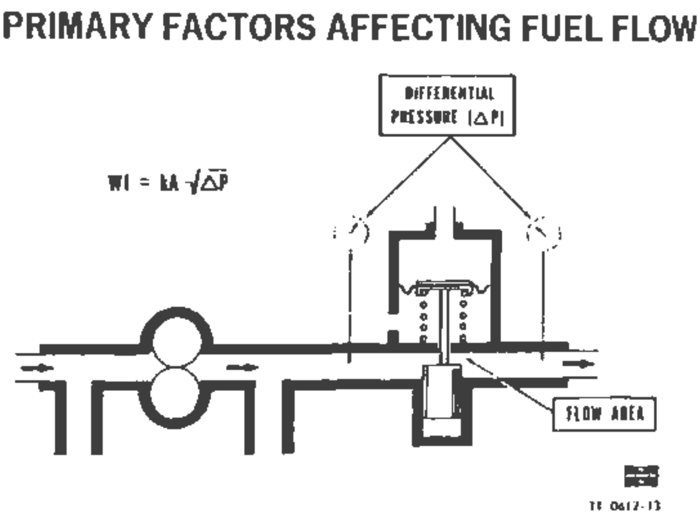
In the system as depicted in this schematic, the metering valve would have no authority over how much fuel was put into the engine. It is obvious that some system must be created that would give this metering valve the necessary authority over the volume of fuel sent to the engine.



#204

In this illustration, assume that the engine is running at a constant speed, driving the pump at a constant rpm, and resulting in a constant volume flow through the pump. A bypass path is provided so that the excess fuel not required in the engine can flow back to the inlet side of the pump. Thus, the pump continues to pump its constant volume.

The bypass valve's position must be coordinated with the position of the metering valve. For example, if we were demanding more fuel by an increase in compressor pressure, the metering valve would open to allow more fuel to flow to the engine. At the same time, the bypass valve would close because there is less of the total flow volume to flow back to the pump inlet. These two valves must work together.



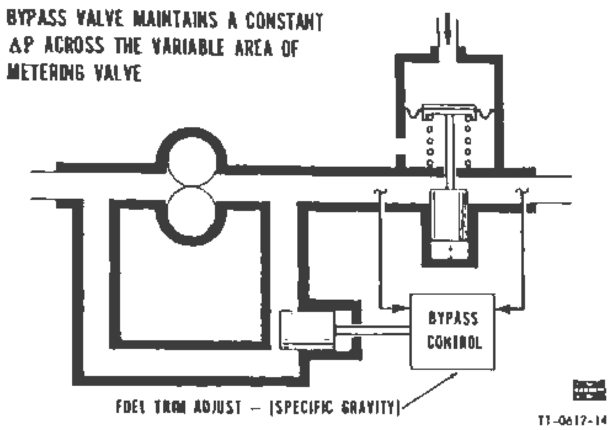
#205

Let's examine the primary factors that affect the flow of fuel through a metering valve. First of all, the metering valve can be described as a "Variable Orifice." The flow of a fluid through any orifice is a function of the size of that orifice and the pressure drop across the orifice. The formula in the upper left hand corner illustrates that relationship between the area of the opening and the differential pressure across that area. For example, assume for a moment that the metering valve is held in a fixed position. The area of that opening is constant. As the fuel flows through that orifice, there is a pressure drop. The two gages indicate that differential pressure across the orifice.

If we restricted the discharge or the downstream side of the metering valve, without changing the position of the metering valve, and eventually caused it to be plugged completely, the pressure differential would reach zero.

Now let's look at the more normal condition of control. If we maintain a constant differential pressure across the metering valve, the amount of flow through the valve would be regulated by its opening, or area.

METERING VALVE AUTHORITY



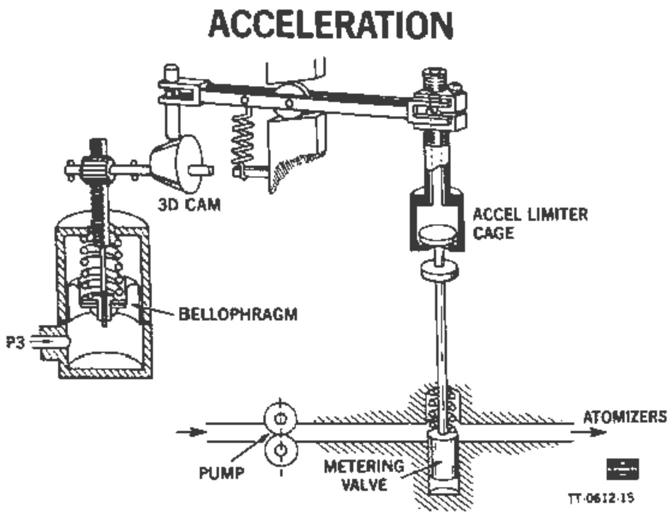
#206

The coordinated movement of the bypass valve and metering valve is accomplished by a "Bypass Valve Control" that senses the pressure drop across the metering valve. Its function is to maintain a constant pressure drop across the variable area of the metering valve. This obviously gives the metering valve the authority to regulate the amount of fuel going to the engine.

As an example, if the metering valve were to move towards an open position, the first tendency would be for the differential pressure to decrease. That decrease would be sensed by the bypass control and it would move the bypass valve towards the closed position to maintain the correct pressure drop across the metering valve. With the same pressure drop and a bigger opening, the metering valve would allow more fuel to flow to the engine. The bypass valve would take in less excess fuel, which it sends back to the inlet side of the pump.

There is an adjustment that will be described later in maintenance actions related to this bypass control.

It is identified as the "Fuel Trim Adjustment," or, as it is sometimes referred to, the "Specific Gravity Adjustment." It is a method of regulating the desired differential pressure to be maintained across the metering valve. More will be said about this in the adjustment procedures.



#207

Even though the line mechanic will not have the occasion to work on the internal details of the fuel control, it is necessary to understand its operation so that logical maintenance actions, such as adjustments and troubleshooting, can take place. Let's first consider the acceleration portion of the engine starting cycle.

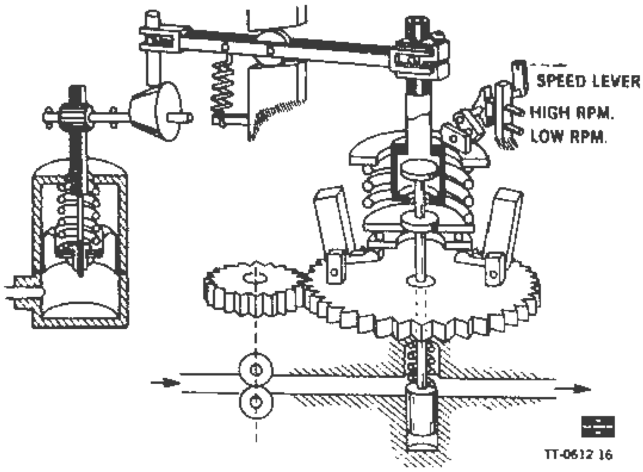
We already know that the fuel flow to the engine during acceleration is a function of P3 air pressure. This schematic identifies those components in the fuel control responsible for the metering of fuel during the acceleration period. The metering valve is spring loaded towards the open position, and is positioned by a rod with a flange encased in the acceleration limiter cage. This cage is attached to one side of a pivoting rocker arm. The rocker arm is spring loaded on the left side to hold a follower arm against a three-dimensional cam. The cam is rotated by a rack and pinion gear attached to the bellophragm assembly shown on the left side.

Once the engine has been allowed to light off, acceleration is a function of the starter cranking and the energy being created in the turbine section by the combustion gases.

As the engine rpm increases, the P_3 signal to the bellophragm increases. The movement of the diaphragm against the spring causes the rack to move up. The pinion gear is rotated and the three-dimensional cam is turned to a higher ramp area, lifting the follower rod. This drops the acceleration limiter cage, allowing the spring to open the metering valve and increase the flow of fuel to the atomizers. The design of the three-dimensional cam assures that, with the proper increase in P_3, we will send the proper amount of fuel increase to the engine to maintain the proper fuel/air ratio.

To illustrate how this knowledge can assist in troubleshooting, let us assume that during a normal start procedure the engine speed tended to slow down in the mid range of rpm. At this point, quick reference to the instruments reveals that the rpm is moving very slowly, the fuel flow is less than normal, and the temperature is less than normal. This is a sure indication that the engine is fuel limited. We can see, under these conditions, that the lack of P_3 signal may be the logical reason for restricting the fuel during this period of acceleration. The bellophragm assembly gets the P_3 signal through external plumbing from the plenum chamber. It is a very simple matter to check this system for leakage.

UNDERSPEED GOVERNOR

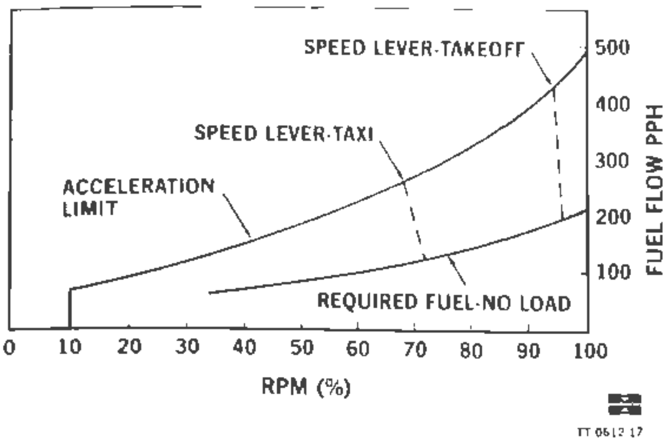


#208

Let's now add a flyweight type mechanical governor to the system. This is the underspeed governor. Notice that the flyweights are mounted on a gear driven by the shaft of the fuel assembly. As the gear increases in speed during acceleration, the flyweights tend to move outward lifting against the bearing and a thrust washer. As the acceleration system was dropping the acceleration cage--allowing the metering valve to open--the flyweight operated thrust washer was moving up. When the thrust washer contacts a flange on the metering valve rod, it has control over the position of the metering valve. The acceleration limiter cage continues to drop and at this point is effectively disconnected from the metering valve. The amount of fuel now sent to the engine will be just the right amount to maintain the engine at the speed selected by the speed lever position.

Notice the high and low rpm limiting stops indicated on the speed lever connection. These are adjustments that will be covered in later discussions on the fuel control.

USG OPERATION



#209

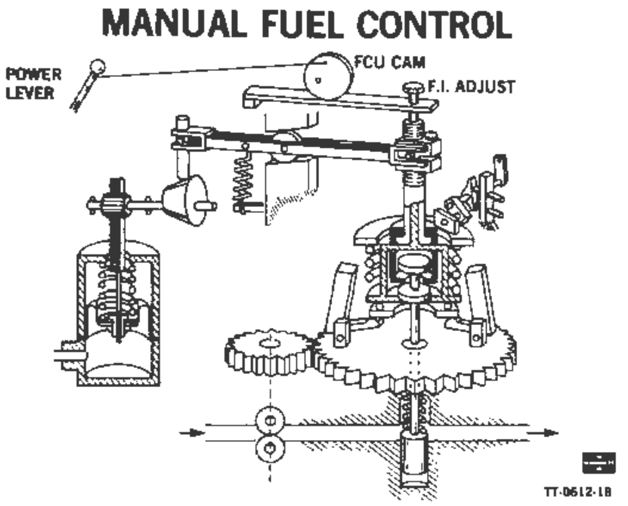
The top line on this curve reviews the fuel flow during a normal acceleration period. As the engine attains 10% speed the fuel is allowed to flow through an opened shutoff valve. During acceleration, the fuel flow curve bears resemblance to the P3 curve. Since the propeller is on the start locks, the load does not essentially change. In order to make the rpm accelerate, the fuel flow must produce power in excess of the load being carried. The underspeed governor that we have just described must stop that acceleration at the desired rpm point.

The lower line on this curve is identified as a "Required-To-Run" line. It identifies the amount of fuel necessary to carry the engine with minimum load to any given rpm. For example, if a normal start procedure were made with the speed lever in the low rpm, or taxi position, an rpm of approximately 73% would be requested on some models of the -10.

Note that as the engine approaches that rpm, the dotted line represents the action of the underspeed governor reducing the amount of fuel necessary to hold that engine at 73 per cent. The dotted line to the right indicates what would happen if the engine were started with the speed lever at the takeoff or high rpm position, calibrating the underspeed governor to 97 per cent. The engine would have a perfectly normal acceleration, but the point where the acceleration would be stopped would now be 97 per cent.

The low rpm, or taxi position, of the speed lever is the usual starting condition.

This will keep the engine at a low rpm and reduce the propeller noise during this stage of operation. The required-to-run line in this curve, is at a no load condition. If the propeller were removed from the locks and the aircraft were taxied by providing an increased blade angle, this increased load would raise the required-to-run line fuel under those conditions of load.



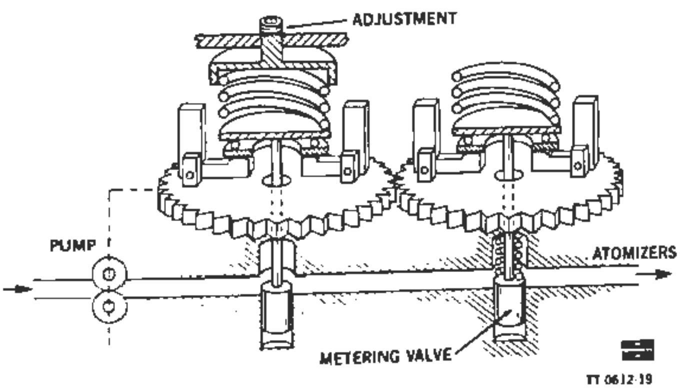
#210

With the speed lever at high rpm, or takeoff, the spring value of the underspeed governor had been increased to result in 97 per cent rpm. As the pilot now moves the power lever--from zero thrust forward towards takeoff condition--mechanical linkage from the power lever rotates a cam in the fuel control. The cam bears down on a mechanical link that extends down through the acceleration limiter cage and bears directly on the thrust washer, adding to the spring force that the underspeed governor spring had been applying. In fact, the mechanical force on that thrust washer actually overpowers the underspeed governor, forcing the flyweights in, allowing the metering valve to be opened to cause additional fuel to flow. From this point on, there is no control by the underspeed governor. The position of the metering valve is directly a function of the power lever rotating the cam in the fuel control and mechanically positioning the metering valve. It is this direct connection that prompted the name "Manual Fuel Control."

The additional fuel results in an increase in rpm from 97 per cent to 100 per cent, in which case the propeller governor will take control of maintaining the necessary blade angle to absorb the power being produced. The engine power management system is now in the propeller governing mode of operation.

You will notice an adjustment point, identified as "Flight Idle Adjust" in the upper right hand portion of this picture. In later discussions on the adjustments on the fuel control, the procedures for adjusting this screw will be covered. It can be seen here that if we select a fixed position of the power lever at flight idle, and change that adjustment screw, we would mechanically increase or decrease the metering valve opening.

OVERSPEED GOVERNOR
OSG HAS PRIORITY OVER METERING VALVE

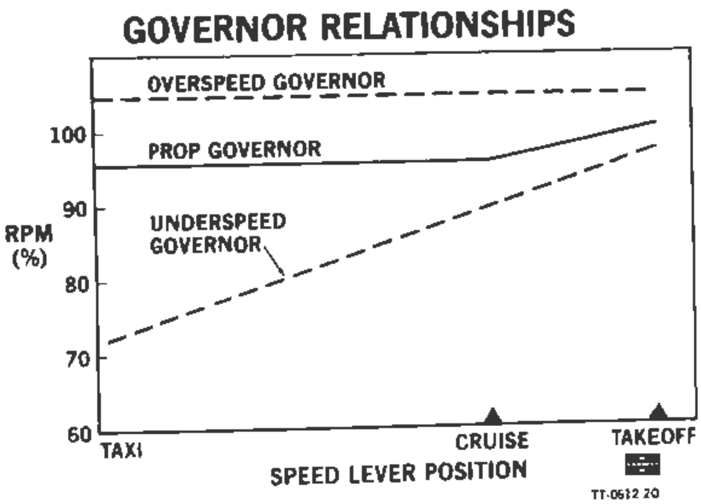


#211

The fuel control includes a mechanical overspeed governor to ensure that the speed of the engine is never permitted to exceed a safe operating limit. Notice that the overspeed governor is upstream of the metering valve and it obviously has priority over the control of the fuel going to the engine. It is adjusted at the fuel control and is not connected to any cockpit controls. As the flyweights move out against the calibrated spring force when exceeding a given rpm, it would restrict the flow of fuel to the engine. Typically, the overspeed governor will be calibrated to limit the rpm to approximately 103 to 105 per cent maximum.

The calibration of the overspeed governor is tested by advancing the power lever to put more fuel into the engine during ground run with the propeller being retained on the locks. Since the propeller governor cannot cause the propeller to accept an increased blade angle to hold the rpm at the governor setting, the rpm will continue above the normal propeller governor setting. Rpm will then be limited by the overspeed governor.

When operating in the normal speed ranges in flight, or on the ground, of 100 per cent rpm or less, the overspeed governor will be sensing an underspeed condition and be wide open allowing the fuel control metering valve to perform its normal function. The overspeed governor will take control only in an emergency to protect the engine from excessive speed.



#212

So far in this book, you have heard about propeller governors, underspeed governors, and overspeed governors. You know when and how they perform their function and what they control. It is appropriate now to examine the three governors as they are related to each other.

You know that the propeller governor and the underspeed governor are mechanically connected to the speed lever control in the cockpit. Across the bottom of this chart the speed lever position is indicated all the way from the low rpm of taxi to the high rpm takeoff position. It can be seen that the speed lever adjusts the spring value in the underspeed governor and the propeller governor within the limits of the governor stops.

It has no effect on the overspeed governor, since there is no connection between the overspeed governor and the speed lever.

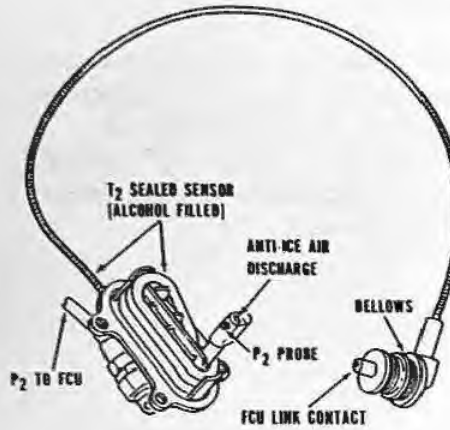
The dotted line reflects the change of calibration of the underspeed governor. The low point of this curve will vary with different aircraft applications from 65 to 75 per cent. Your maintenance manual will define the particular numbers for your application. The solid line identifying the propeller governor adjustment indicates a range of 100 per cent to 96 per cent at cruise. Further reduction of the speed lever will have no effect on propeller governor setting.

Notice that at any position of the speed lever, there is a separation between these governors. The separation must be at least two and one half per cent rpm. For example, if the speed lever were at the takeoff position, the spring of the underspeed governor would have been calibrated to 97 per cent and the spring in the propeller governor to 100 per cent, a separation of three per cent. The overspeed governor and its setting are indicated by approximately 104 per cent. This is a good separation and no governor will interfere with the operation of another governor.

This minimum separation must be maintained to prevent the overspeed governor from attempting to meter the fuel when you are operating on the propeller governor, and to prevent the propeller governor from attempting to meter oil pressure when you are operating on the underspeed governor.

If all governor adjustments are made to the correct values of the maintenance manual, you will not have problems of governor interference.

P2 T2 SENSOR



- P_2 T_2 SENSOR SIGNALS TO FCU COMPENSATE FUEL SCHEDULES AS A RESULT OF AMBIENT PRESSURE/TEMPERATURE CHANGES
- T_2 ALCOHOL SOLUTION DYED RED

TI-0612-21

#213

As the aircraft flies in varying temperatures and pressure altitude conditions, the density of the air changes and the metered fuel must be modified as a result of these changes. The Woodward fuel control utilizes a "P_2 T_2 Sensor" system inserted in the inlet of the engine to measure the temperature and pressure of the air entering at Station Two, which is the compressor inlet. This system will automatically compensate the fuel under these varying density conditions so that there is no requirement for the pilot to adjust the power lever.

The P_2 probe identified on the sensing element is a total pressure pickup. The air pressure sensed at this probe will be sent through plumbing connected to the fuel control unit. This pressure is available to a bellows that will position the three-dimensional cam to make the adjustment necessary to the metered fuel. There is a supply of warm air from the compressor section made available to make sure that P_2 probe does not ice up.

The T_2 system is made up of a sealed tube assembly filled with an alcohol solution. Increasing air temperature flowing over the coil of the T_2 sensor will cause the fluid to expand. The expansion of the bellows will adjust the linkage assembly within the fuel control to make the necessary correction to the metered fuel.

The alcohol is mixed with a red dye to provide visible evidence of a leak in this sealed system. The bellows assembly that attaches to the fuel control, should be carefully inserted into the opening on the fuel control to ensure that the bellows is properly seated before tightening the screws that hold it in place.

START FUEL SYSTEM

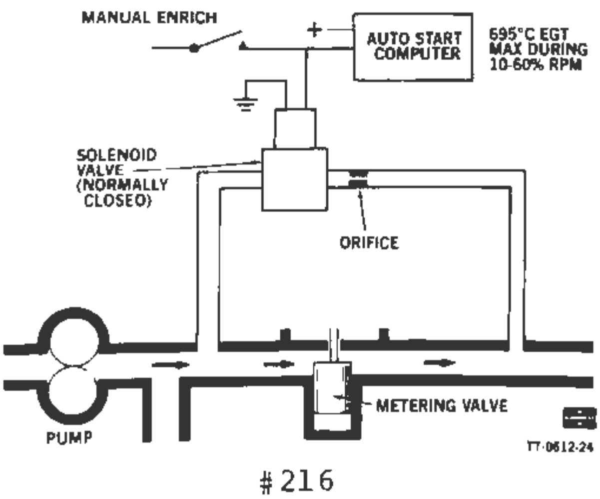
- ENRICHMENT
  SOLENOID VALVE ORIFICE
- AUTO START COMPUTER
  SPEED SWITCHES
- FILTER ANTI-ICE LOCKOUT
- PRESSURIZING VALVE

TT-0612-23

#215

The Start Fuel System consists of: Enrichment, an Auto Start Computer, a Filter Anti-Ice System and a Pressurizing Valve. Each of these devices will be explained in detail on the next few pages.

ENRICHMENT SYSTEM

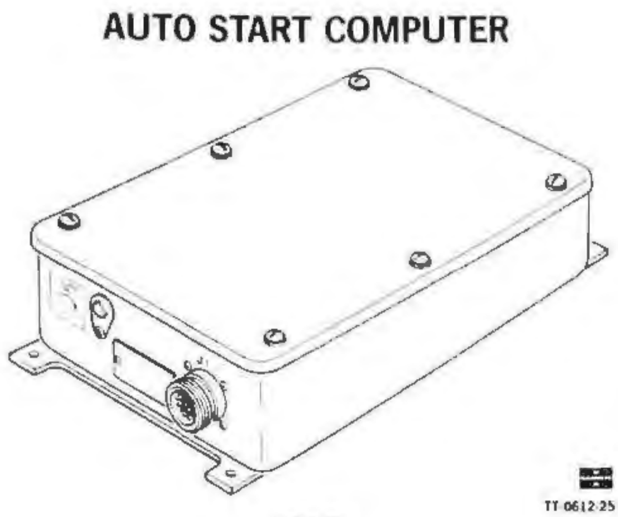


#216

The fuel control, as previously described, regulates the amount of fuel for acceleration after lightoff by P_3 air pressure rotation of a three-dimensional cam. Under certain ambient conditions, there may be a need for additional fuel during this period of acceleration. The critical considerations are that the acceleration be rapid enough to minimize the time spent in the critical frequency range, and that this rate of acceleration must be accomplished without exceeding the maximum turbine temperature limit of 770° Celsius EGT for a maximum time of one second.

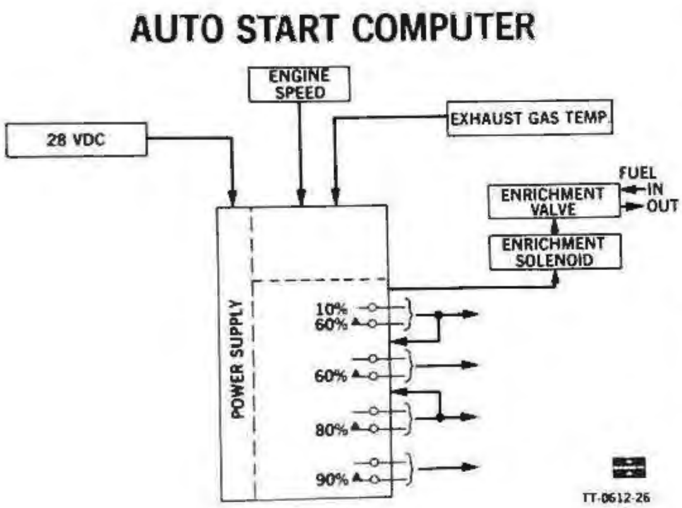
Normal system operation is as follows. Pump discharge pressures are available to the upstream side of a normally closed solenoid valve. As 10% rpm is reached, the auto start computer signals the solenoid valve to open, allowing fuel pressure to the fixed orifice. This orifice will allow approximately 25 to 50 additional pounds per hour of fuel flow downstream of the metering valve, thus bypassing the fuel control. As the EGT increases to 695° Celsius, the auto start computer would de-energize the solenoid valve and close it.

The auto start computer will open and close the enrichment valve during the normal start procedure to maintain the temperature near the 695° point. This provides a smooth and rapid acceleration without exceeding the 770° temperature limit. Above 60 per cent rpm, the system is deactivated and has no further effect. Manual override of the computer signal can be accomplished with a cockpit switch.



#217

The auto start computer is a remotely mounted control containing speed switch and enrichment control functions. Additional systems included in the control relative to the EGT single red line system will be covered in Section Eight on the Temperature Indicating System.



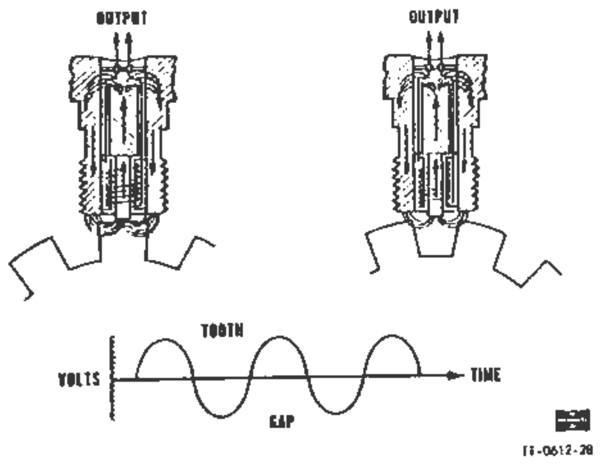
#218

This simplified schematic indicates computer input and output signals that are related to the automatic start function. It should be noted that in the upper left a source of 28 volt dc power from the aircraft system is the first input. Other inputs include an indication of an engine speed signal and exhaust gas temperature. The output signal on the right side is to the enrichment solenoid, as previously described.

The bottom right hand side of the box includes a series of speed switches. These switches are operated as a result of the engine speed input signal and will complete circuits to various components within the engine system. For example, at 10% rpm, the fuel shutoff valve needs to be opened, the ignition system needs to be turned on, and the enrichment system needs to be armed.

At 60% rpm, starter cut out, ignition cut out and oil vent valve closure, are typical examples of actions that must be accomplished. This is representative and more will be said of the operations of these switches in the future discussions. At this point, it is important to realize that in the 331, the engine speed signal comes from a monopole in the propeller governor.

MONOPOLE PRINCIPLE

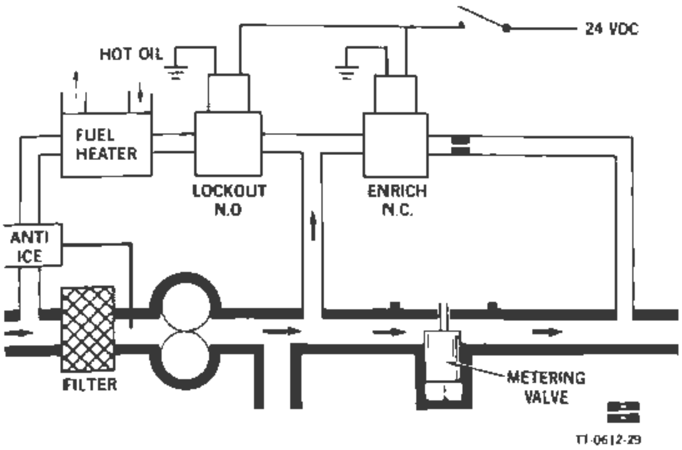


#220

The monopole pickup is a variable reluctance device used to measure engine rpm. Each monopole contains internally a soft iron core attached to the end of a permanent magnet. The coil of wire surrounds the core, terminating at an electrical output connector. The pickup is positioned in close proximity to the teeth of a special rotating gear in the propeller governor. The permanent magnet causes magnetic force lines that are commonly known as "Lines of Flux." As the gear rotates with engine rpm, each gear tooth approaches and passes the monopole tip. Reluctance varies and the flux lines build and collapse inducing a measurable voltage into the coil. During buildup and collapse of the field, this induced voltage reverses polarity and provides an ac voltage. This ac signal frequency is recognized by the computer as an indication of engine rpm.

The ac signal strength produced by the monopole is calibrated by adjusting the dimension between the magnet and the gear tooth. Detailed procedures for calibrating monopoles will be included in the Woodward governor publications.

ANTI-ICE LOCKOUT SYSTEM

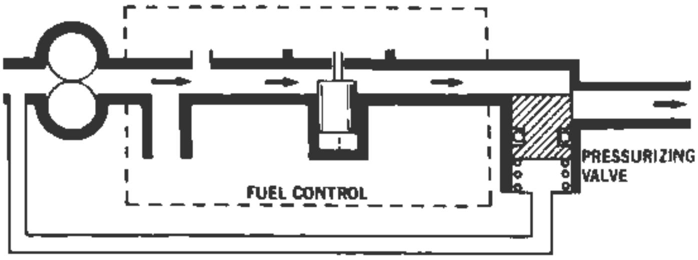


#221

This schematic not only illustrates the fuel filter anti-ice system, but also includes the enrichment system previously described. During the start cycle, the priority of the enrichment system is obvious. It is more important that available fuel is sent to the enrichment system for good acceleration than to be concerned with anti-icing the fuel system filter. This priority is simply accomplished by the solenoids operating in opposite directions. The lockout solenoid is a normally open solenoid. The enrichment solenoid is a normally closed solenoid. When the electrical system applies power to open the enrichment solenoid, that same power will close the lockout solenoid. Once the engine has reached normal rpm, the lockout solenoid valve would remain open allowing fuel to be available through the fuel heater up to the anti-ice valve. When the temperature sensing element of the anti-ice valve senses that the temperature of the fuel in the area of the filter is getting to a point less than 40° Fahrenheit, the anti-ice valve would open. The warm fuel from the fuel heater would mix with the inlet fuel and would keep the filter from icing.

PRESSURIZING VALVE

PROVIDES WORKING FUEL PRESSURE IN FCU DURING INITIAL CRANKING



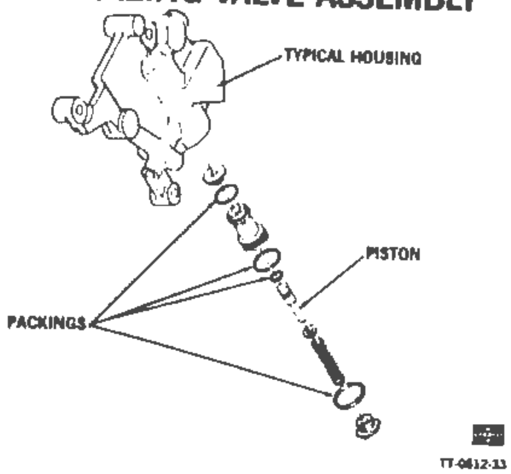
TT-0612-31

#223

This schematic shows the addition of a spring loaded valve mounted external to the fuel control, called a "Pressurizing Valve." Its purpose is to provide the appropriate working fuel pressures within the fuel control. As the fuel pump starts turning, fuel pressures are felt to the top of the pressurizing valve. That pressure must build to 125 psi to compress the spring of the pressurizing valve and move the piston downward. It is during this period of initial cranking that the internal pressures within the fuel control are utilized for such things as the P_2 sensor system. During normal operation, the pressurizing valve is wide open and contributes nothing to the control of fuel.

Only two problems can develop with the pressurizing valve. If it were stuck in a closed position, there would be no fuel exiting from the fuel control, even though the fuel pump pressures would be high. The other problem could be internal leaking of the "O" ring on the piston. Excessive leakage would allow the fuel pressure to get back to the inlet side of the pump. This might prevent sufficient fuel for lightoff.

PRESSURIZING VALVE ASSEMBLY



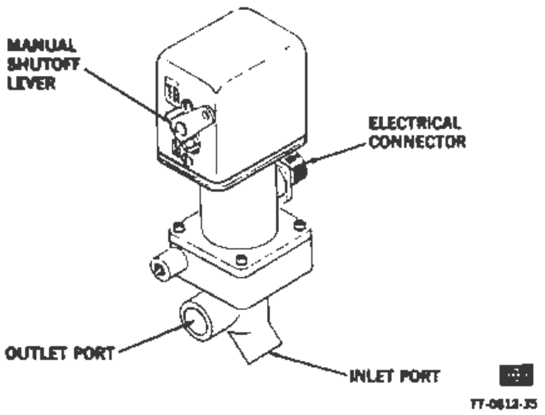
#225

The appearance of the pressurizing valve in its housing varies with installations of the 331 Engine. The majority of installations utilize the housing shown here. This housing is bolted to the side of the Woodward fuel control.

It is interesting to note that on some installations of the 331 Engine, the enrichment valve, anti-ice lockout valve, and the pressurizing valve are incorporated in one housing attached to the side of the Woodward fuel control.

Regardless of the housing design on various installations, the internal parts of the pressurizing valve are identical. The spring force must be overcome by 125 pounds of fuel pressure in order to force the piston downward and allow the fuel to flow on to the engine. The most likely problem that can occur with the pressurizing valve will be damage to one or more of these packings. If the packings leak, they can allow the fuel to bypass to the inlet side of the pump. The possible result will be insufficient fuel for lightoff. The mechanic should exercise extreme caution when removing the pressurizing valve so that none of the small parts are lost.

FUEL SHUTOFF VALVE

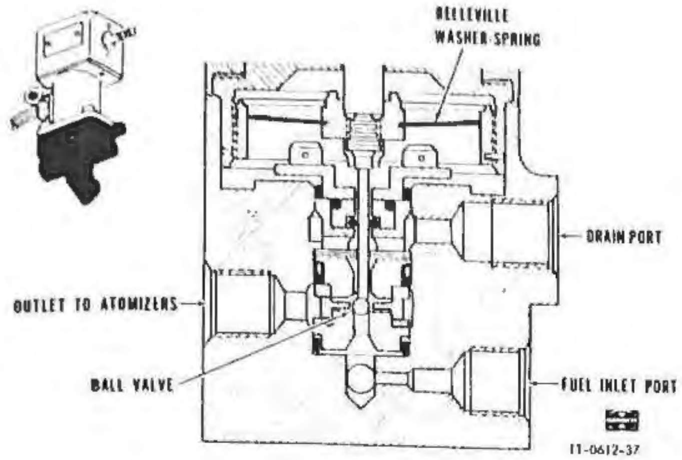


#227

Let's review quickly what we have learned about the engine fuel system up to this point. You now know that the aircraft supply of fuel is made available to an engine driven pump assembly and is metered by a fuel control assembly to provide the right amount of fuel. The fuel control is assisted by the starting system components. The next component we need to discuss is a "Fuel Shutoff Valve" needed to meet the requirements of providing fuel to the engine at the appropriate time.

Obviously, the initial fuel to the engine will be required at the time when lightoff is desired. The fuel shutoff valve will be electrically opened by a signal from the auto start computer speed switch at 10% rpm. The fuel shutoff valve must, of course, stay open throughout all engine operations so that fuel will be available to the engine. To shut the engine off, the valve is electrically closed by a signal from the cockpit stop switch. The valve can also be closed by the manual shutoff lever shown on the side of the housing. This lever is rigged mechanically to the cockpit emergency shutoff control. When the emergency control is activated, it will shut off the fuel and then stroke the feather valve to allow the propeller to go to the feathered position. The fuel shutoff valve is mounted on the left side of the engine.

SHUTOFF VALVE - LATCHING



#229

The fuel shutoff valve can be separated into three sections which contain the major elements within the valve. The very bottom of the valve includes the valve and a latching device. The round section in the center includes the electrical coils for opening and closing the valve. The top portion includes switches and springs.

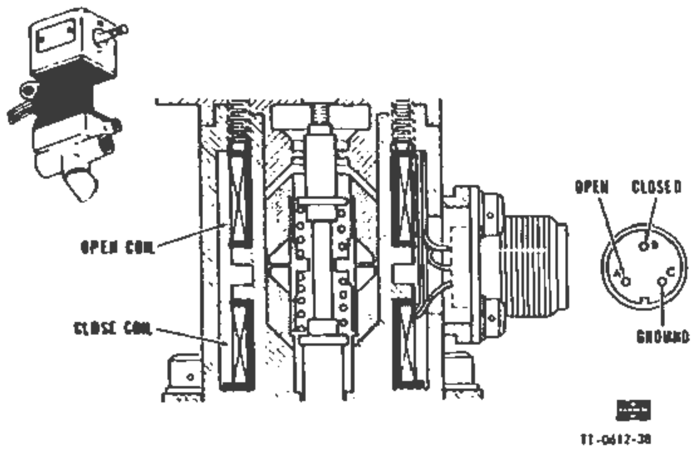
The dark portion of the valve in the upper left of this illustration indicates the fuel portion of the fuel shutoff valve. The larger schematic shows the ball valve to be a very tiny ball on the seat. When the ball is on the seat, the fuel from the inlet cannot pass to the outlet. When the rod allows the fuel to raise the ball from the seat, fuel is free to flow through the outlet to the atomizers.

There is a requirement on fuel shutoff valves established by the FAA. The requirement states that the fuel shutoff valve cannot depend on electrical power to keep it in an open position, because obviously, the loss of dc power to the solenoid would allow the valve to go to the closed position and shut off the fuel to the engine. This requirement is met in this device by the belleville washer spring shown near the top of the actuating rod.

The spring is presently shown in the position in which the ball is closed. As the actuating rod would be moved upward to open the valve, the belleville spring would be snapped over the center. This then becomes a latching device used to mechanically hold the valve in the open position and no further electrical power is required.

In order to close the valve, it then becomes necessary to apply a closing force through the actuation of a closing solenoid to force the rod downward and snap the belleville spring over the center, latching the ball against the seat in the closed position. If electrical power were not available to close the valve, the only way it could be closed would be by the emergency manual shutoff.

SHUTOFF VALVE - ELECTRICAL

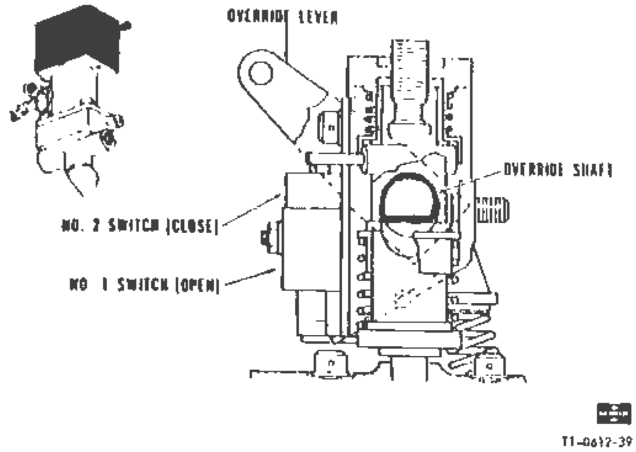


#230

The black section in the upper left hand picture identifies the electrical portion of the fuel shutoff valve. As we examine the schematic, we see that there is an open coil on top and a closed coil on the bottom. The coils attract the center plunger, either up or down, depending on which coil is energized. Movement of the plunger provides the spring forces necessary to stroke the center shaft.

The electrical connector has three pins. C is common ground. Pin A is to the open coil and pin B to the closed coil. The aircraft wiring system will put power to pin A through the 10% speed switch. Power to pin B will come from the shutoff switch.

SHUTOFF VALVE - MANUAL



#231

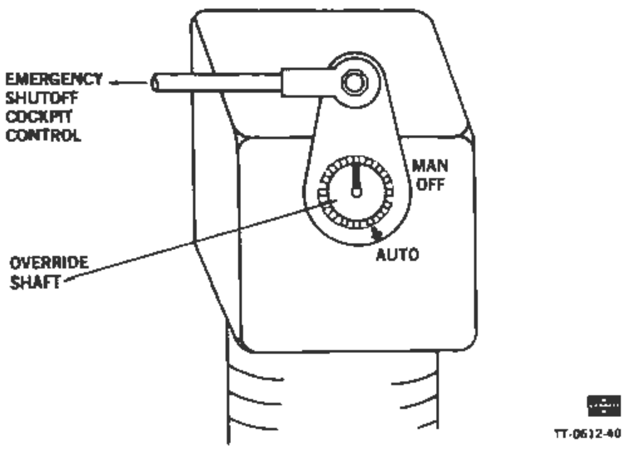
This illustration shows one view of the top portion of the fuel shutoff valve. There are two microswitches. Number one is the "Open" and number two is the "Closed" switch. We can also see in the dotted line the override lever that is attached to the override shaft. When electrical power is put to pin A to cause the valve to open, the coil is energized, causing the center core to stroke upward. A pin attached to that shaft will contact the plunger on the number one switch, and will break the circuit to the opening coil. When pin B is energized to close the valve, a roll pin on the top of the shaft comes down and contacts the plunger on the number two switch, breaking the power to the closing coil. This means that electrical power is applied to the coils for a very short period of time. This allows the coils to be built very small since they are not subjected to continuous electrical power. Proper checking and adjusting of these switches will be covered in a later section.

The manual override function can best be illustrated by looking at the cross-sectional view of the override shaft. When the override shaft is in the position shown, it will allow free action of the electrical opening and closing of the valve. When the override shaft is rotated 90 degrees in either direction, the flat spot in the override shaft acts as a cam and will cause a large spring force to be applied to the mechanical portion of the valve and will also activate the microswitch that will break the circuit to pin A, thus no electrical power can be applied.

The valve is now manually closed. The cockpit emergency shutoff control must be returned to the normal position before the valve can then be electrically opened. The valve cannot be opened by movement of the manual shaft.

In summary, the valve can be opened and closed electrically, and can be closed, but not opened, manually

SHUTOFF VALVE - RIGGING

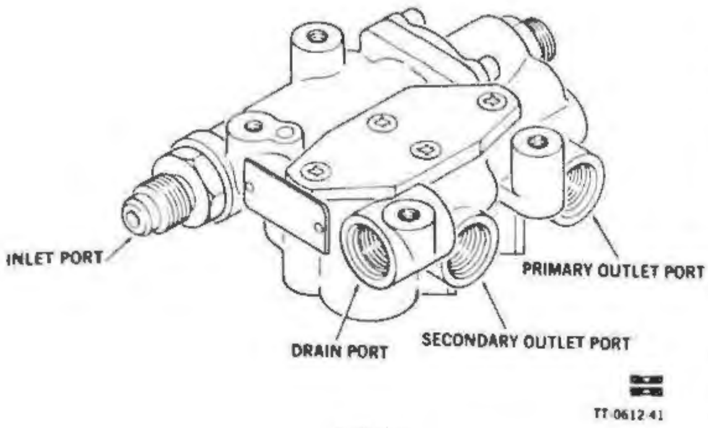


#232

The lever arm attached to the spline shaft on the fuel shutoff valve is usually provided by the aircraft manufacturer. This lever normally has an arrow on it to point to the appropriate indication on the valve cover to show whether the valve is in an automatic position or is manually off. Installation of this lever on the splined shaft is critical. To assist in properly mating the two parts, the override shaft on the valve has a scribe mark on the end of the shaft. When this scribe mark points to the 12 o'clock position, the override shaft is in the auto position, allowing normal electrical operation. The lever then should be installed on the spline shaft with the arrow pointing to the automatic position.

Rigging instructions for the emergency shutoff cockpit control to the fuel shutoff valve and the feathering valve are contained in the aircraft maintenance manual.

FLOW DIVIDER



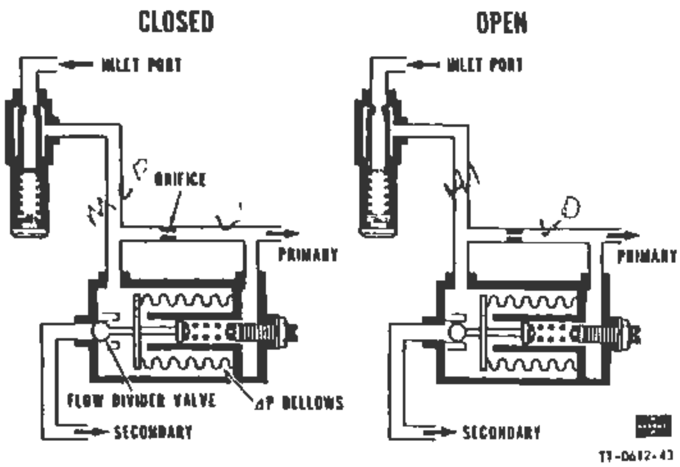
#233

As the metered fuel flow leaves the fuel shutoff valve at 10% rpm, it is sent to the "Flow Divider." It is the responsibility of the flow divider to send the metered fuel to the appropriate fuel manifold, depending upon the conditions of the engine. During start and lightoff, all the fuel must be directed to the primary fuel manifold in order to obtain good spray characteristics. As the engine accelerates, the small holes of the primary atomizer nozzles will not be capable of carrying the volume of fuel necessary to produce power. The flow divider senses this condition in fuel flow and will appropriately direct the fuel to the secondary manifold, in addition to the primary manifold. The combination of both manifolds will flow the volume of fuel into the engine necessary to produce power.

The flow divider is completely automatic in operation, and has no controls in the cockpit. The major ports are identified in this illustration. On the left side is the inlet port, receiving the fuel from the fuel shutoff valve. On the lower right hand side you can see one port to the secondary manifold and one port to the primary manifold. There is also a drain port which will be discussed later.

Flow dividers are mounted on the bottom side of the power section on all 331 applications.

FLOW DIVIDER OPERATION



#235

One of the major components within the flow divider necessary for its action is a self-bypassing type, fuel screen at the inlet. Notice that the fuel coming into the screen flows through the screen, and on into the bellows assembly. Should the filter become restricted, causing sufficient differential to oppose the spring force, it will push the screen down and allow a bypass of fuel to the flow divider. Checking this screen is one of the maintenance actions and will be discussed later.

Consider the illustration on the left. The fuel is available out of the filter to flow through the orifice, and to the primary manifold. Notice that a pressure tap from upstream of the orifice puts that pressure on the outside of a bellows. It cannot escape from that area since the flow divider valve is against its seat and no fuel flow goes to the secondary manifold. Downstream of the orifice is a pressure tap going to the inside of the differential bellows. Obviously, as fuel flows through the restriction of an orifice, it causes a pressure drop. That pressure drop will provide the force necessary to stroke the bellows to the right at a given point of differential pressure.

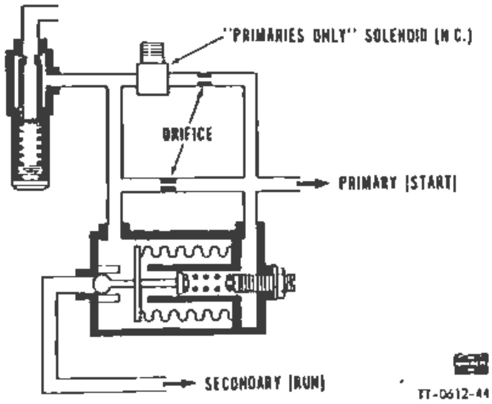
The picture on the right shows that the fuel flow has been increased through the orifice sufficiently to cause the pressure differential to move the bellows to the right. This opens the flow divider valve, allowing fuel in that outer chamber to flow to the secondary manifold. The primary manifold continues to flow fuel.

The pressure drop created by a calibrated orifice working in conjunction with the spring rate of the differential bellows is calibrated so that the bellows will start opening the flow divider in the 331-10 Engine at approximately 45 pounds per hour flow of fuel through that orifice.

This calibration value is determined by several important considerations. One will be the amount of fuel necessary to assure the best possible combustion characteristics in flight and at altitude. The 45 pound per hour calibration is based on the desired distribution of the total fuel flow between the secondary manifold and the primary manifold.

"PRIMARIES ONLY" CALIBRATION

RECALIBRATES FLOW DIVIDER FROM 10-80% RPM

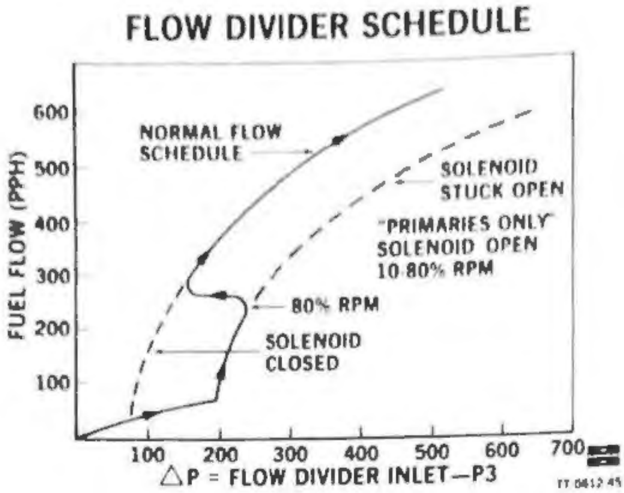


#236

The calibration point of 45 pounds per hour for opening the flow divider is particularly suited to the improved combustion at altitude. This amount of fuel to the primary manifold prior to the flow divider opening would not be enough for ideal starting characteristics. In order to obtain the appropriate spray from the primary atomizers, they must have approximately 70 to 115 pounds per hour. The "Primaries Only" system, illustrated here, recalibrates the flow divider opening point to this higher value during the accelerating time from 10% to 80% rpm. This recalibration is accomplished by adding a second orifice parallel to the previously described flow orifice. Upstream of this orifice is a normally closed electrically operated solenoid valve.

When the engine accelerates past the 10% point, the auto start computer will put a signal to the "Primaries Only" solenoid and energize it open allowing fuel to flow through both orifices in parallel. Obviously, to sense the same calibrated point of pressure differential across the bellows, both orifices must flow a greater volume of fuel. When the flow of the two orifices approaches 70 to 115 pounds per hour, sufficient pressure differential will then be felt across the bellows to start to stroke the flow divider valve open.

When the engine is accelerated past the 80% point of rpm, the auto start computer speed switch will remove the power from the "Primaries Only" solenoid. This closes off the parallel orifice and recalibrates the opening of the flow divider back to the 45 pounds per hour flow, causing the appropriate share of fuel to be carried by each of the manifolds. On some aircraft installations of the -10 Engine, the aircraft electrical system will include a time delay in the circuit that will close the "Primaries Only" solenoid. This 30 second delay in closing the solenoid will assist in better air starts where a windmilling propeller will accelerate the engine faster than the normal ground start utilizing the starter motor.



#237

This curve provides the information for troubleshooting the "Primaries Only" system. Notice that the left side is total fuel flow in pounds per hour and across the bottom will be a pressure indication of the difference between flow divider inlet pressure and pressure at the discharge side of the atomizers which is P_3. If a malfunction was suspected in this system, a mechanic could install a pressure gage to measure flow divider inlet and P_3. The cockpit instrument indicates fuel flow in total pounds per hour.

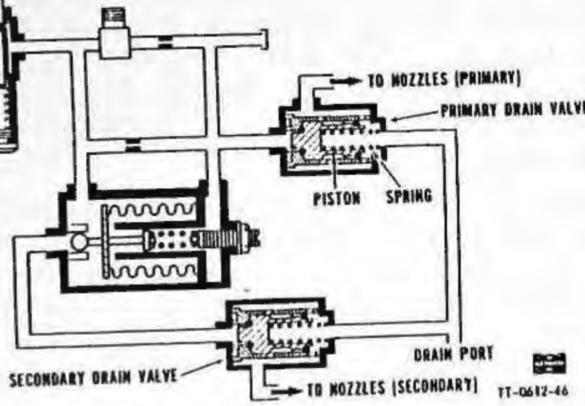
The solid line with arrows on this curve identifies what happens during normal operation. The dotted lines will indicate the type of pressure that may be seen under certain conditions of malfunction of the "Primaries Only" system.

You can see by following the normal operating solid line that as the engine accelerates, the fuel pressures increase rapidly until flow has reached 70-115 pounds per hour. At this point, the flow divider would open, according to the calibrated schedule, with the "Primaries Only" solenoid open. The increase in volume of fuel with relatively little increase in pressure indicates that we now have both manifolds flowing the fuel. When 80% rpm is reached and the "Primaries Only" solenoid is closed, an immediate reversion to the lower calibration point is seen. The flow divider would move further open, reducing the back pressure and you can see that an increasing fuel flow with lower pressure values is then assumed. This is normal.

If the solenoid remained closed, you can see that the pressure rise would be higher for the increase in fuel flow that we would experience during the initial phases of acceleration. This would open the flow divider too early and would cause improper lightoff spray.

If the "Primaries Only" solenoid were to remain open all the time, you can see that operation would be normal up to the 80% point, but then the flow schedule following the dotted line indicates higher pressures are needed to gain the necessary additional fuel flow. The pilot would experience no difficulties in engine operation under these conditions, but the benefits of proper fuel distribution through the manifolds in flight would be lost. This could result in excessive carbon formation in the combustion section.

FLOW DIVIDER - DRAIN VALVES



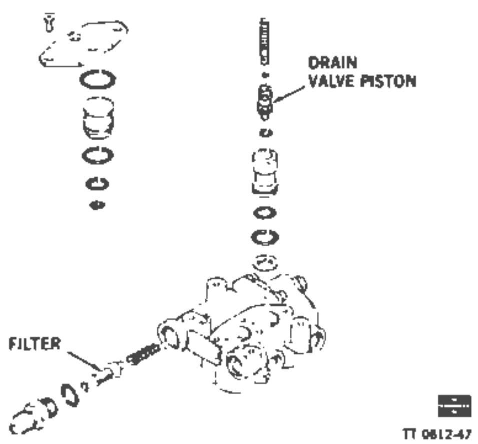
#238

When an engine is shut off, it is important that the fuel remaining in the fuel manifolds is removed and not permitted to dribble into the plenum chamber. The presence of this raw fuel in the hot section of an engine on shutdown could cause a fire at the next attempted start. Included in the flow divider assembly are two drain valves: one in the primary system and one in the secondary system. These are spool valves that are lightly spring loaded to the closed position. As fuel enters the left side of the primary valve, it will bear against the piston and cause this spool to move to the right against the spring force. The fuel will flow through the spool and the cage proceeding outward to the primary nozzle manifold.

The drain valve stays open to fuel through all operations. The right end of the spool seats against the right end of the cage and seals off a drain line. As the engine accelerates, the flow divider opens the flow divider valve and fuel is allowed to open the secondary drain valve.

At the time of engine shutdown, fuel pressure immediately drops in the flow divider. As the fuel pressure is reduced at the inlet of the two drain valves to a point less than the spring value, the spring returns the spools to the left side and opens the port on the right end connected to the drain port. The air pressure that remains in the plenum chamber will remove the fuel by pushing it back through the manifolds, drain valves, and out the drain port on the flow divider, thus purging the fuel from the manifold system.

FLOW DIVIDER ASSEMBLY

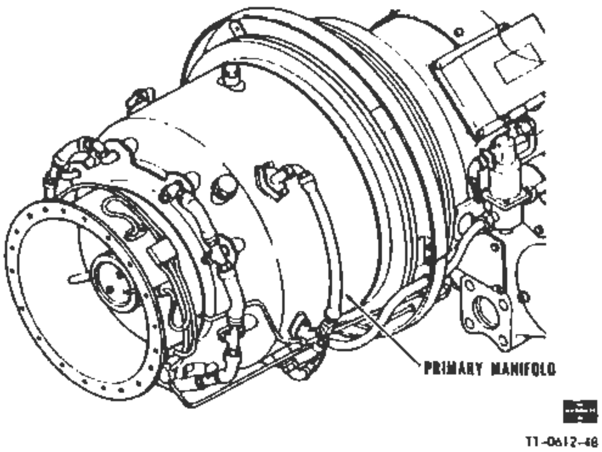


#239

This is an illustration of the flow divider showing an exploded view of those elements of the flow divider that require maintenance actions. The self-bypassing spring loaded filter is shown in the lower left. It is a metal screen and should be cleaned periodically.

The exploded view of a typical drain valve indicates the presence of a number of packings as well as the spring and the piston assembly. Care must be taken in disassembly of this component so that parts are not lost.

PRIMARY FUEL MANIFOLD

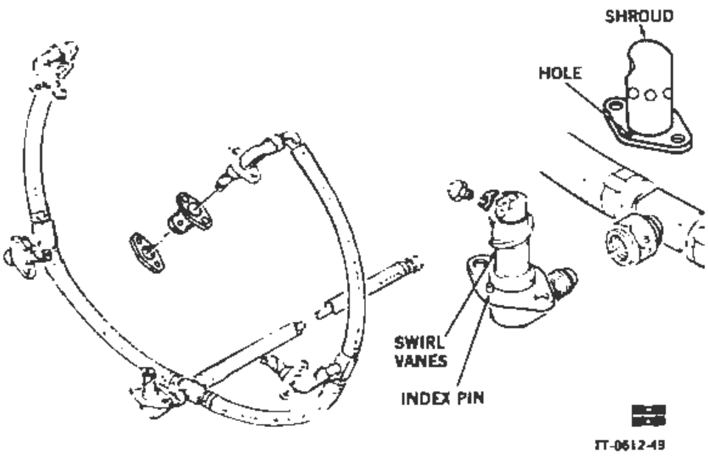


#240

The "Primary Manifold" is mounted around the outside of the plenum chamber. It carries the fuel from the flow divider to five small atomizer nozzles that extend through the plenum chamber into the combustion section of the engine.

The primary manifold is sometimes referred to as the "Start Manifold" since its obvious function is to provide the correct fuel during the start condition.

PRIMARY NOZZLE/SHROUD



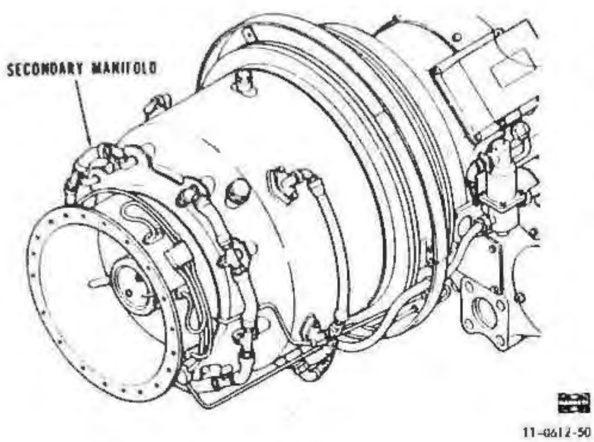
#241

In this picture you can see the fuel manifold on the left that contains connections to five separate nozzle assemblies. Each assembly consists of the nozzle body itself, including the atomizer tip and an air shroud and gasket.

The lower picture on the right shows the nozzle body with the atomizer tip removed. The nozzle body has swirl vanes that cause some of the compressor discharge air to create a swirling action around the discharge of the atomizer to aid in better vaporization of the fuel and to air wash the atomizer tip to prevent carbon buildup. It is obvious that with the atomizer tip mounted at an angle, the shroud must be installed in one way only. To ensure this proper indexing, the nozzle body flange contains an index pin that will mate with a hole in the flange of the shroud.

Maintenance personnel should be very careful to make sure that these two parts are mated properly before attaching them to the plenum chamber mounting flange.

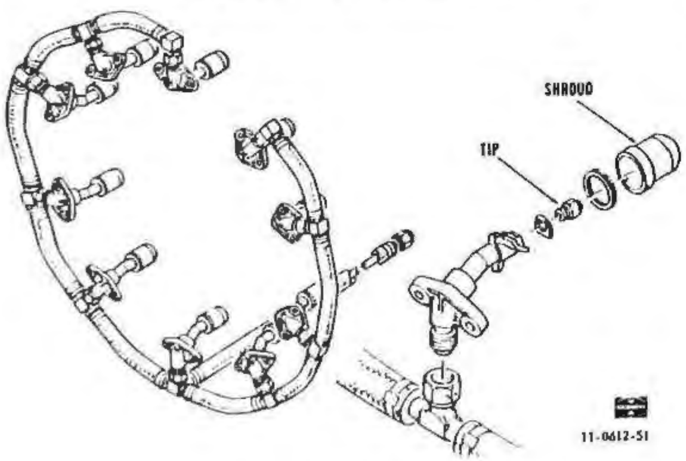
SECONDARY MANIFOLD



#242

The "Secondary Manifold," carrying the fuel from the flow divider to ten larger atomizer tips, can be seen mounted on the aft end of the plenum chamber. This manifold is often referred to as the "Run Manifold," since the prime purpose of this manifold is to carry the large volume of fuel necessary to produce the power required.

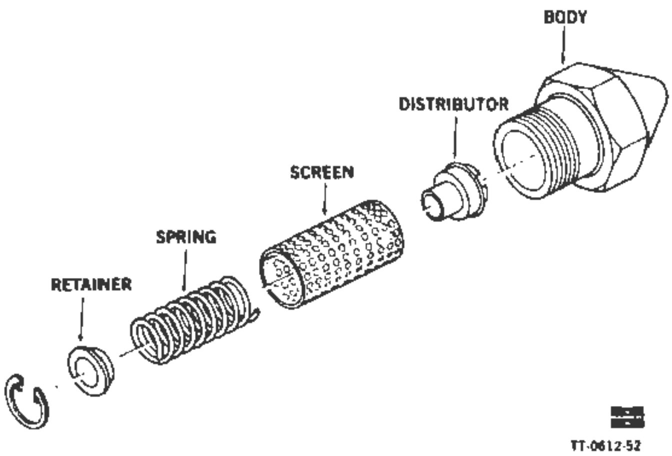
SECONDARY NOZZLE/SHROUD



#243

This drawing shows that the secondary manifold supports ten nozzle assemblies. The nozzle assembly includes the nozzle body with its swirl vanes, an atomizer tip, and an air shroud.

ATOMIZER TIP

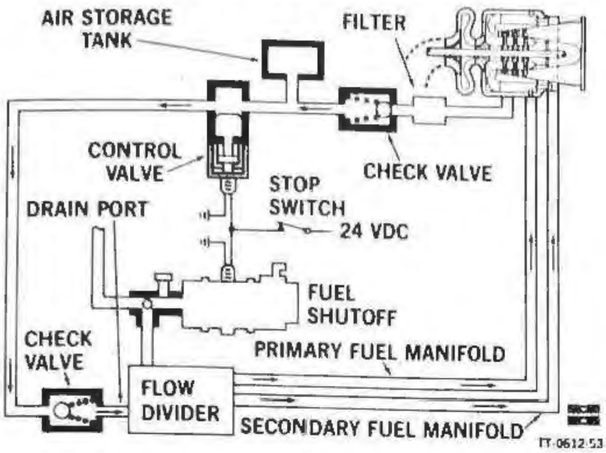


#244

This is an exploded view of the components contained within a typical atomizer tip. All of the tips in the primary manifold are the same and all of the tips in the secondary manifold are the same. They are not interchangeable between the two manifolds. The distributor is installed in the body and is designed to create the proper swirling action to result in a correct spray angle and proper atomization. The distributor is held in the body by a spring. The spring is surrounded by a screen to filter any possible contamination that may have escaped the previous filters in the fuel system. The spring is held in place by a retainer and a snap ring.

The engine maintenance manual provides detailed instructions for cleaning, inspecting, repairing, and testing atomizer tips for the 331 Engine. The operator who desires to accomplish these detailed repair procedures, should have the appropriate test equipment so he is able to flow check the atomizer tip after reassembly. The costly damage that may be incurred in the turbine section by an improperly repaired atomizer tip warrants doing the job right or not doing it at all. If the operator does not have the proper test equipment, it is completely acceptable to exchange the tip and replace it with a new one. The old tips may be returned for repair to a qualified repair station.

FUEL MANIFOLD PURGE SYSTEM



#245

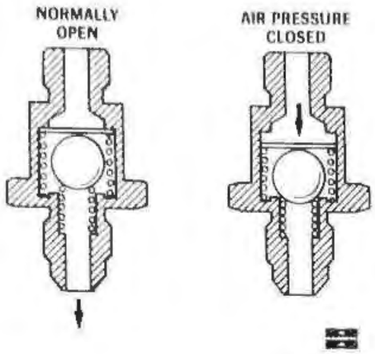
When we discussed flow divider operation, we identified the spool type drain valves that allowed fuel to drain from the manifolds out a drain port on the flow divider. In recent years, the Environmental Protection Agency has issued regulations prohibiting the discharging of fuel into the atomsphere. The "Fuel Manifold Purge System" pictured here has been designed to utilize air pressure to push that fuel into the engine and burn it as the engine is being shut down.

At the upper right hand portion of this illustration we see that a source of P_3 air pressure is plumbed from the engine through a filter and a one-way check valve into an air storage tank. Downstream of the tank is an electrically operated shutoff valve that can discharge that air down to a check valve attached to the drain port of the flow divider. During normal operation, the electric shutoff valve will be closed and P_3 air will pressurize the air storage tank. The check valve on the flow divider drain port will be seated, preventing the possibility of any internal fuel leakage from getting back into the pneumatic purge system. When the stop switch is completing the circuit to the fuel shutoff valve to energize it closed, it also energizes the control valve in the purge system to the open position. Since the P_3 pressure in the storage tank is higher than the P_3 pressure from the engine at reduced speed, the differential pressure closes the check valve downstream of the filter.

Thus, the only way out for the air stored in the tank, is to discharge through the open control valve, unseat the check valve on the flow divider drain port and push the fuel that remains in the manifolds into the combustion section to be burned before the flame goes out. This will result in a slight increase in rpm, just after energizing the stop switch closed. That slight increase in rpm is an indication that the purge system is operating normally.

It is important for the engine to run at least 95% rpm prior to shutdown so that the charge in the air storage tank will be high enough to satisfactorily purge the system. It is also advisable to hold the stop switch circuit to the control valve for at least five seconds, or until the engine rpm has dropped below 50%. This provides the time necessary to discharge the air storage supply through the flow divider and completely purge the manifolds. These operating instructions will be emphasized in the Pilot's Operating Handbook.

PLENUM DRAIN VALVES

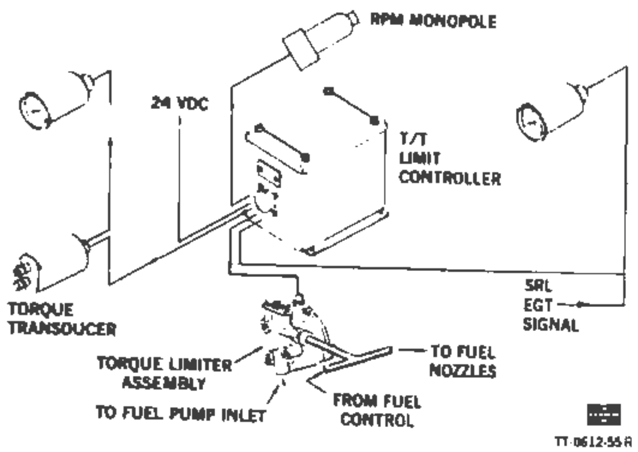


#246

To make sure that no level of liquid remains in the engine plenum chamber, two "Plenum Drain Valves" are installed as shown in the illustration in the upper left. The illustration of the normally open valve indicates a spring loaded ball being held up against a spring loaded screen, when the engine is not running. This permits discharge through an overboard vent line. It's obvious that if we allow a drain line to be open during engine operation, we could lose valuable power. When the engine starts to rotate, a pressure of approximately two and one half to five psi bearing against the top of the screen will overcome the spring and force the ball down against the seat, sealing off the plenum chamber and preventing the loss of any compressor discharge air pressure.

A very simple check can be accomplished by locating the drain line, overboard from the nacelle. While the engine is operating at ground idle, put your hand over that drain port. If you feel a hot air discharge, then you have a drain valve that is stuck open. There should be no P_3 air loss during the time the engine is operating.

TORQUE/TEMP LIMIT SYSTEM

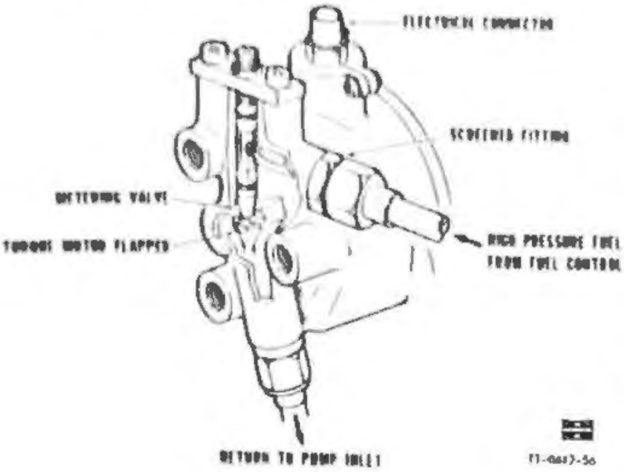


#247

Earlier in this book, the point was made that the power derived from the 331 Engine is limited by a maximum torque value or a maximum temperature point, whichever occurs first. The system illustrated here is designed to automatically limit the power to these torque/temperature limits.

With the limiter system turned on, the pilot may advance the power lever to make maximum torque for takeoff. The maximum torque will then be limited by the automatic system and he can direct more attention to the handling of the aircraft. The torque/temperature limit controller receives its input signals from the torque/temperature indicating systems. (These indicating systems will be discussed in detail in later sections.) The propeller governor monopole is sending an engine speed signal to the limiter controller and there is also a 24 volt source of dc power. The one output of the controller goes to the torque limiter assembly, which is a fuel bypass valve. When either the torque or temperature limit is reached, this bypass valve is driven to an open position sufficient to bypass enough fuel back to the fuel pump inlet to keep the engine from exceeding those limits.

LIMITER FUEL BYPASS VALVE



#248

This artwork illustrates the major portions of the "Limiter Fuel Bypass Valve." The metered pressure on the way to the atomizers is connected to the right side of this valve. The discharge, on the bottom of the picture, returns to the pump inlet. The metering valve, shown in the center, is a calibrated orifice closed by a torque motor operated flapper valve. When the valve receives a signal at the electrical connector from the torque/temperature limit controller, it will move the flapper valve away from the orifice sufficiently to allow the right amount of fuel to bypass back to the inlet side of the pump. It appears that this could cause a problem to the engine if this valve were to malfunction in the wide open position. However, this valve has a fail safe feature. The metering valve is a calibrated orifice that will limit the maximum flow being bypassed to approximately 100 pounds per hour when fully opened. This amount is adequate to assure the valve's operation as a limiting device, but is small enough so that the total flow through a wide open orifice would not starve the engine from fuel.

Note that there is a screen in the inlet line. This is a maintenance action item that needs periodic inspection.

MAINTENANCE ACTIONS

- FILTERS
- ADJUSTMENTS
- ATOMIZER FLOW CHECKS
- TROUBLESHOOTING

TT-6612-57

#249

We have now covered all of the major components in the fuel system. Your understanding of the operation of these components should now provide a base from which your maintenance actions can be effectively accomplished.

The remainder of this section will be devoted to covering maintenance items such as filter inspections, adjustments to the fuel control, atomizer checks, and some corrective actions as indicated in the troubleshooting section.

MAINTENANCE ACTIONS

FUEL SYSTEM FILTERS/SCREENS

- AIRCRAFT FUEL SUPPLY SYSTEM
- ENGINE FUEL PUMP
- FLOW DIVIDER INLET
- ATOMIZER TIP
- T/T LIMITER INLET
- PURGE SYSTEM - AIR FILTER

TT-6612-58

#250

It is vital that the fuel system be effectively filtered to prevent any malfunction that could cause extensive damage to the turbine section. The aircraft maintenance manual will describe the filter inspection procedures for the aircraft fuel supply system filters. The rest of the filters on this list are identified in the engine maintenance manual inspection procedures.

The main engine fuel filter is in the pump assembly. The next filter point is the self-bypassing inlet filter on the flow divider. The screen in the atomizer tip would be an inspection item during a repair and overhaul operation. The torque/temperature limiter bypass valve, just described, also has a screen on the inlet. These are all fuel filters. There is also an air filter in the manifold purge system that should be periodically inspected and cleaned.

MAINTENANCE ACTIONS

ADJUSTMENTS

- **FUEL CONTROL**
  - FUEL TRIM (SPECIFIC GRAVITY)
  - OVERSPEED GOVERNOR
  - UNDERSPEED GOVERNOR HIGH/LOW
  - FLIGHT IDLE FUEL FLOW
  - MAXIMUM FUEL FLOW
- **START SYSTEM**
  - COMPUTER ENRICH TEMPERATURE
- **SHUTOFF VALVE**
  - MICRO SWITCHES
- **TORQUE/TEMP CONTROLLER**
  - TEMP LIMIT ADJUST

TT 0612-59

#251

Proper operation of the 331 Fuel System is dependent largely upon the maintenance manual authorized adjustments to the components in the system. It will be necessary upon installation of a new fuel control that all adjustments be checked and adjusted, as necessary, to ensure the proper operation of the fuel control. Troubleshooting a fuel system to correct some malfunction may occasionally involve nothing more than the proper adjustment of one of the components. You can see on this list that the fuel control has a number of adjustments authorized by the maintenance manual. These will now be covered individually.

There is an adjustment on the auto start computer relative to the maximum temperature where the enrichment system will shut off. The fuel shutoff valve has authorized adjustments of the micro switches and the torque/temperature controller has an adjustment to the temperature limit point.

FCU ADJUSTMENT CRITERIA

ADJUSTMENT	CRITERIA
FUEL TRIM (SP GR)	MATCH FUEL
OVERSPEED GOVERNOR	ENGINE RPM PROP ON LOCKS
UNDERSPEED GOVERNOR	ENGINE RPM
HIGH	P/L = G.I. S/L = TAKEOFF
LOW	P/L = G.I. S/L = TAXI
FLIGHT IDLE FUEL	AIRCRAFT RATE OF DESCENT
MAXIMUM POWER	MAX EGT - FLIGHT/GROUND DO NOT EXCEED TORQUE LIMIT

IT-8612-80

#252

BENDIX

ORDER 1. FUEL TRIM

2 OSG

3 START FLOW

4 USG H

5 USG L

6 MAX PWR

7 FI FUEL

In order to cover all of the authorized adjustments on the fuel control, assume that you have just replaced a fuel control and are going to go through the complete adjustment procedure. The list on the left side of this chart indicates the sequence normally followed. On the right side we have identified the criteria for that adjustment. For example, there is an adjustment on the Woodward fuel control identified as "Fuel Trim." It is referred to in some instances as the "Specific Gravity Adjustment." The criteria for this adjustment is to match the specific gravity of the fuel being used. During the discussion on the fuel control, we identified that the bypass valve was adjusted by this specific gravity adjustment. The purpose of the bypass valve was to maintain a constant pressure drop across the variable metering orifice. Normally this adjustment is positioned in the middle of the range and you will have little reason to change it, unless a change in fuel type prevents the engine from producing takeoff power.

The overspeed governor check is made with the engine running and the propeller on the locks. This adjustment is located inside the fuel control, as you will see in the next picture.

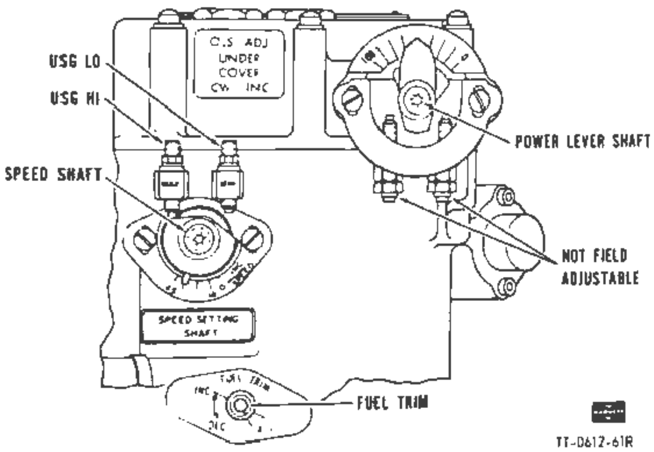
The underspeed governor has two adjustments, the high stop and the low stop. In order to test the high stop position, the power lever would be at the ground idle position, with the propeller off the locks and the speed lever at the takeoff position.

The underspeed governor low stop would be checked with the power lever still at the ground idle position, but the speed lever returned to the taxi or low rpm position.

The flight idle fuel flow adjustment relates to aircraft sink rate.

The final adjustment on the Woodward fuel control is the maximum EGT attainable without exceeding the torque limit. This may have to be done as a result of flight test depending upon the ambient conditions under which the test is being made. If the ambient temperature is high enough to permit attaining maximum EGT without exceeding torque limit, this adjustment may be checked on the ground run.

FCU ADJUSTMENT LOCATION



#253

This illustration is a view of the Woodward fuel control looking down from the top. On the left side near the center, is the speed lever shaft. It's shown here against the underspeed governor high stop adjustment. Maintenance manual instructions will identify each of these adjustments and how much effect in rpm will be the result of each revolution of the adjustment.

On the bottom of the picture, you see the adjustment identified as "Fuel Trim" adjustment. This adjustment accepts an Allen wrench and has a scribe mark acting as a pointer. Remember, this screw is adjusting the value of the bypass valve in order to increase or decrease the pressure differential maintained across the main metering valve.

On top of the illustration is a nameplate on the cover of the control that identifies that the overspeed governor adjustment is located under the cover. We will identify this location on a later drawing.

On the upper right hand side is the power lever shaft. It has two stops limiting its travel. These stops are adjusted on a flow bench and are not identified in the manual to be field adjustable.

FUEL TRIM ADJUST

CHANGE IN FUEL TYPE

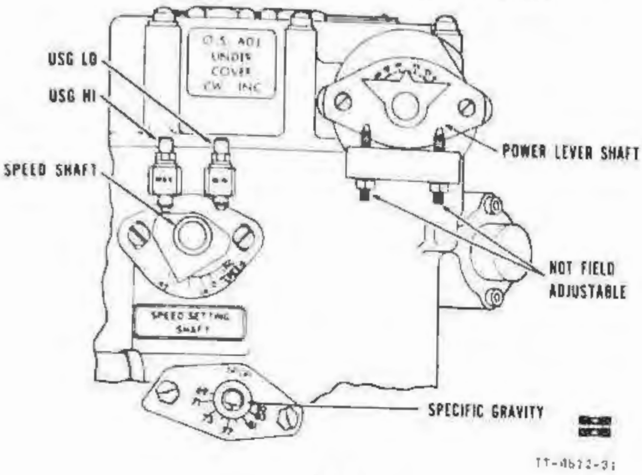
FROM	TO	FUEL TRIM ADJUST
JP 5 (JET A)	AV GAS	CW 6 CLICKS
JP 5	JP 4	CW 3 CLICKS
JP 4 (JET B)	AV GAS	CW 3 CLICKS
AV GAS	JP 4	CCW 3 CLICKS
JP 4	JP 5	CCW 3 CLICKS
AV GAS	JP 5	CCW 6 CLICKS

TT-0012-79R

#254

This chart gives typical fuel trim adjustments as a result of changing type of fuel. The first example involves changing from JP5 to an emergency use of an approved AV gas. Six clicks clockwise would adjust the fuel control to compensate for the lower energy level of the AV gas. Obviously, the adjustment should be returned to the proper position when the normal fuel is being used.

FCU ADJUSTMENT LOCATION



#254A

As mentioned earlier, a variation of the "Fuel Trim" adjustment, found on earlier models of the Woodward fuel control, is the adjustment identified as the "SP. GR.," or "Specific Gravity" adjustment. This adjustment is identified in the lower part of this drawing of the fuel control. Although the nomenclature differs--from "fuel trim" to "specific gravity"--the purpose of these adjustments remains the same. Namely, to accommodate a change in the type of fuel being used.

FUEL SPECIFIC GRAVITY

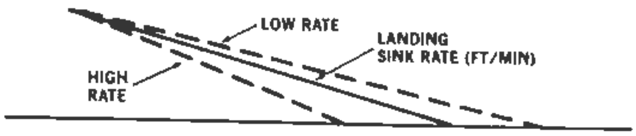
FUEL TYPE	RECOMMENDED SETTING
JET A	.80
JET A-1	.80
JET B	.77
JP 4	.77
JP 1	.81
JP 5	.83
AV GAS 80/87 OCTANE	.69

TT-0694-42

#254B

The chart shown here provides information regarding the fuel type adjustments which are made in accordance with the numerical value of the fuel's specific gravity.

FLIGHT IDLE FUEL FLOW ADJUSTMENT



P/L = F.I.   S/L = HIGH RPM

- SINK RATE IS AFFECTED BY THRUST
- THRUST IS A FUNCTION OF BLADE ANGLE/FUEL FLOW
- CHECK F.I. BLADE ANGLE PER AIRCRAFT MANUAL
- F.I. FUEL FLOW IS ADJUSTED TO DESIRED SINK RATE
- ADJUSTMENT IS VERIFIED BY FLIGHT TEST

TT-0612-62

#255

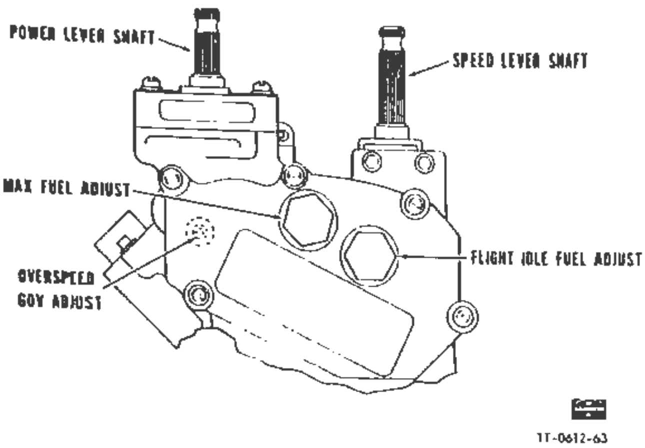
During the landing procedure, the pilot moves the power lever back to the flight idle detent just prior to touchdown. At the point during landing where the power lever is at flight idle, the sink rate of the aircraft is a function of the aircraft trim and weight and the thrust that is being produced by the propulsion system. The Pilot's Operating Handbook will identify the acceptable rate as established during aircraft certification. There will be a minimum and a maximum permitted.

Most pilots would prefer their sink rate to be set near the high tolerance, allowing them to land on shorter runways. If the pilot goes into a long runway, he can always maintain the airline approach by keeping the power lever further forward of flight idle and come in with power. The only sink rate adjustment the mechanic has is to change the thrust being produced under these conditions. The thrust is a function of the blade angle and the fuel flow, or power, that the engine is producing.

As the aircraft flares for landing, the engine drops in speed below the propeller governor and the degree of blade angle will be that blade angle established by the mechanic's adjustment of flight idle blade angle. The blade angle must be that angle identified in the aircraft Pilot's Operating Handbook. Once the mechanic is satisfied that the blade angle is correct, he can turn to the flight idle fuel flow adjustment as his method of adjusting thrust. There is no way that the mechanic can simulate the conditions of the aircraft landing while the aircraft is sitting on the ground.

After any adjustment to flight idle fuel flow, sink rate should be verified by flight test.

FCU ADJUSTMENT LOCATION



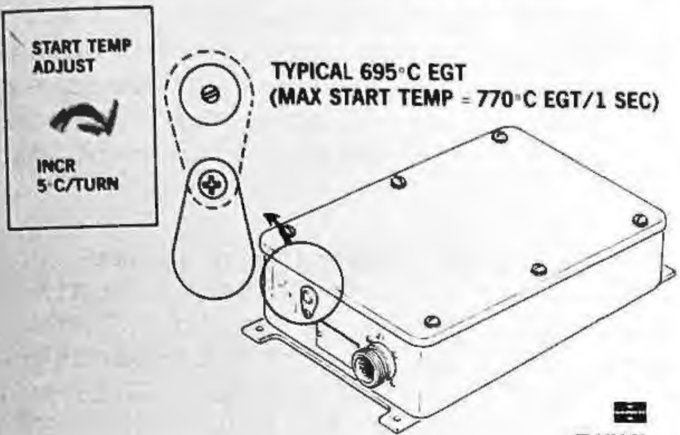
#256

This illustration is a view of the Woodward fuel control looking at the aft end of the control. The two shafts are identified as the "Power Lever Shaft" on the left and the "Speed Lever Shaft" on the right. The "Maximum Fuel Adjust" is under the cover in the upper center of the view. The "Flight Idle Fuel or Intermediate Adjust" is on the right side. The dotted lines show the "Overspeed Governor Adjustment" location underneath the cover of the Woodward fuel control.

The case of the Woodward fuel control is sealed. You will remember that P_2 pressure is plumbed to the fuel control and is the pressure that is maintained within the internal portions of the control. Whenever a cover is removed from the control, attention must be paid to the condition of the packings and gaskets to ensure that the case is resealed.

SRL

ENRICH TEMP LIMIT ADJUSTMENT

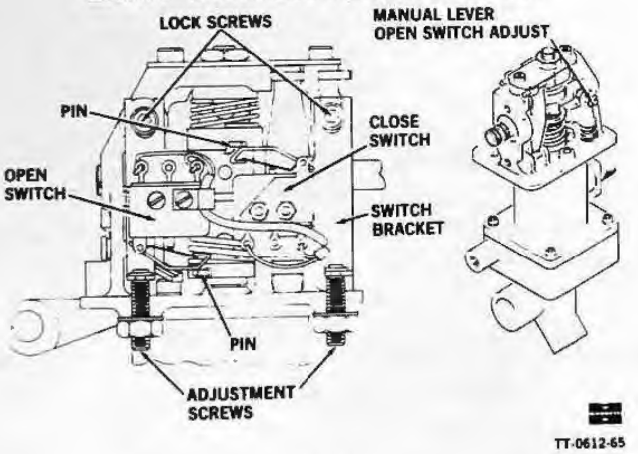


#257

Automatic enrichment--as controlled by the auto start computer--assures rapid acceleration through the critical frequency range without exceeding a safe temperature limit. That limit of 695° Celsius Exhaust Gas Temperature, is safely below the maximum limit of 770°. There is an adjustment for this 695° point located underneath the cover plate on the end of the controller, as shown.

The illustration on the left indicates that the screw holding the cover plate has been loosened and has been allowed to swing out of the way, uncovering the adjustment screw. Turning that screw in a counterclockwise direction would increase the control point approximately 5 degrees Celsius per turn.

LIMIT SWITCH ADJUSTMENT



#258

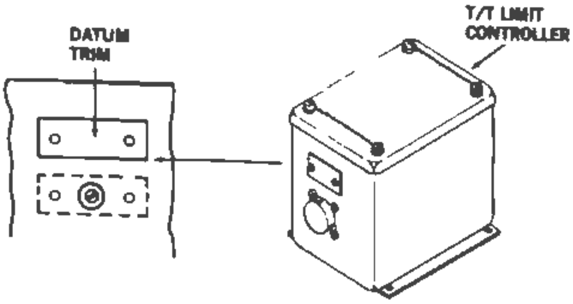
The drawing on the left shows the two microswitches mounted in the control head of the fuel shutoff valve. These switches are used to break the circuits to their respective coils once the valve has been stroked either open or closed. With the lock screw loosened, the adjustment screw on the bottom of the bracket is turned to move the entire bracket, including the switch, up or down. The actuating pin that contacts the micro switch is permanently mounted in the actuating mechanism.

The view on the right side of this illustration shows the other side of the switch housing. It identifies the point for adjusting the lever contact that will actuate the open switch when the manual lever has been turned to the off position.

This will break the circuit to the open coil so that any time the valve is manually closed, electrical power may not be applied to the coil. Detailed procedures for these adjustments are covered in the engine maintenance manual.

TEMP LIMIT ADJUSTMENT

MAX POWER LIMIT = 650°C EGT



#259

The "Torque/Temperature Limit Controller" has only one adjustment available to the mechanic. This adjustment affects the temperature limit calibration point. This will normally be 650° Celsius EGT. The adjustment is located underneath a nameplate identifying "Datum Trim." The illustration on the left side of this picture shows the cover plate has been removed exposing the adjustment screw indicated below. This adjustment screw has a total range of adjustment of approximately 10° Celsius.

ATOMIZER FLOW CHECKS

- PNEUMATIC FLOW
  PNEUMATIC TEST KIT
- ALTERNATE METHOD
  RUNNING THE ENGINE
- FUEL FLOW
  SHOP FLOW TEST EQUIPMENT

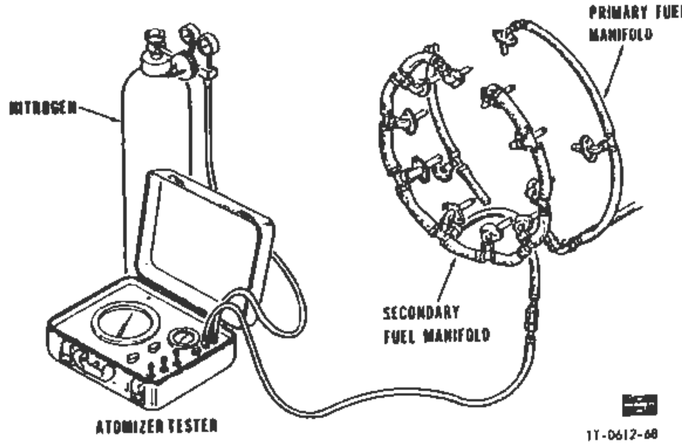
#260

Proper maintenance of the atomizer tips is probably the best example of the advantages of preventative maintenance in the 331 Engine. If the tips are allowed to become restricted and provide distorted fuel flow, the resulting hot spots can cause extensive damage to the turbine parts. Improper fuel spray can result in a variety of problems ranging from hot spots and buckled sections in the combustion liner, to completely melting away portions of stators and turbine blades. The engine maintenance manual covers a variety of checks that allow the operator to select that option most suitable to his requirements.

Several preliminary procedures involve testing the manifold and nozzle system as they are installed on the engine. Other procedures describe the flow testing of these atomizers in a shop environment utilizing the appropriate flow test equipment. There are some advantages and some disadvantages to each of these check procedures. These will be identified as we discuss the three methods indicated here.

The first one is a pneumatic flow utilizing a test kit to check the system as installed in the engine. Secondly, there is an alternate method that involves instrumenting the fuel system and running the engine. Thirdly, there is a shop procedure for flow testing the individual atomizer.

PNEUMATIC FLOW TEST



#261

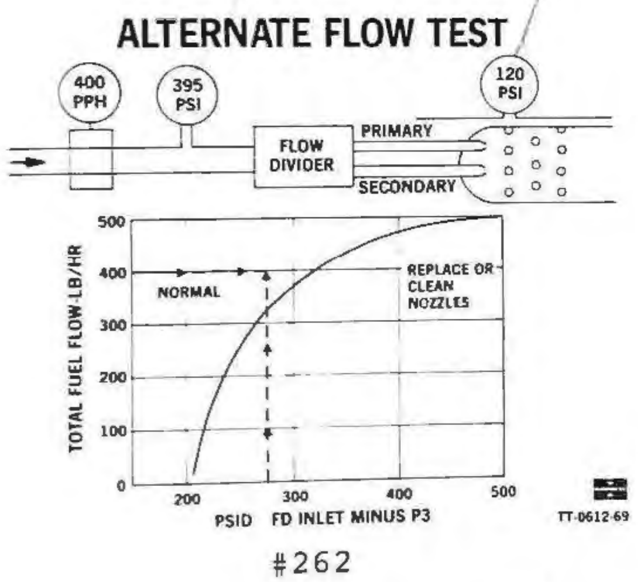
The pneumatic flow test described in the maintenance manual utilizes a source of clean Nitrogen or dry air in conjunction with a tester as connected to the individual manifold. The principle of operation involved in this procedure is that through proper selection of the controls on the tester, the flow capability of air in either manifold can be compared to a master orifice in the tester. The master orifice is carefully sized to represent total flow of all nozzles within one of the manifolds. After establishing a base pressure condition through the master orifice, the tester is switched over to measure actual flow through the manifold. The pressure gages will then indicate whether that manifold represents a smaller or larger orifice than the master.

It is a procedure that can be accomplished on both manifolds in a very short period of time in the hangar since the engine does not need to be operated.

This procedure does not check the actual fuel spray condition that exists at each atomizer. It can be recommended as a good low cost preliminary test that may indicate the need for further investigation. It can often serve a useful purpose in troubleshooting a fuel limited problem as an indicator that maintenance actions on the atomizers are needed.

FUEL

P_3



#262

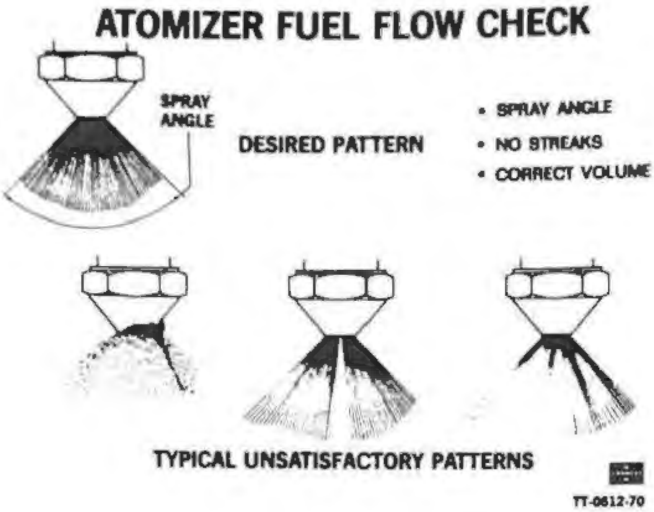
FUEL PR. − P_3 = TRUE FUEL PRESS.

One of the flow test procedures that can be used is referred to as the "Alternate Flow Test." This is a procedure that uses instrumentation to measure the pressure drop across the flow divider and both manifolds under given flow conditions. Reference to a curve shows us when the pressure drop is an indication of some restriction in that part of the system.

We can illustrate this operation by using sample numbers. The engine is running at a stable condition utilizing 400 pounds per hour fuel, and the flow divider inlet pressure is 395 pounds. By subtracting 120 pounds P_3 air pressure from the 395, we would have 275 psi differential pressure between those two points. Locate 275 on the bottom of the curve and follow the arrows vertically to intersect a line representing the 400 pound system flow.

That intersect point is on the left side of the curve, indicating a relatively normal pressure drop across that part of the system. If the nozzles were restricted, the pressure differential would be much higher and probably put the intersect point on the right side of the curve, indicating that further investigation should be made.

This check requires only standard test gages. It also tests the system under actual engine running conditions while fuel is flowing through the system. Unfortunately, this procedure does not check the actual fuel spray conditions of each atomizer tip, and you cannot identify the problem area as the flow divider, a primary or a secondary system. You only know that the total pressure drop across those three components is normal or higher than it should be. This procedure certainly can be a valuable troubleshooting tool to indicate the need for further investigation.



#263

The best way to guarantee that the atomizer tips are good is to flow test each tip in the proper flow bench test equipment. Spray angle and proper volume flow can be tested under actual fuel flow conditions. By examining the illustration on the top of this picture, you can see that the desired pattern should consider the correct spray angle as specified in the maintenance manual. This angle will be different for primary and secondary atomizers. The spray indicated in this picture is evenly distributed and there are no unusual streaks of solid fuel, or distorted pattern, as indicated in the three examples at the bottom. Checking the correct volume flow through each tip under test conditions assures us that the volume at each of the tip locations is within a very close tolerance of being the same for all tips. None of the other check procedures described can accomplish this examination of the individual atomizers.

The engine maintenance manual describes the test equipment necessary to accomplish the flow check. It would not be economically feasible for every operator to invest in this kind of test equipment. However, any operator can certainly replace the tips with new ones and send the removed ones to a facility that has the appropriate test capabilities.

TROUBLESHOOTING AIDS

- **MANUALS**
  - TROUBLESHOOTING CHARTS
  - MAINTENANCE PROCEDURES
- **ENGINE OPERATION**
  - COCKPIT ENGINE PANEL
- **AIRCRAFT PERFORMANCE**
  - SINK RATE
  - ASYMMETRICAL THRUST
- **TEST INSTRUMENTATION**
  - SPECIAL TEST EQUIPMENT
  - PRESSURE GAGES
- **SYSTEM UNDERSTANDING**

IT-0612 TL

#264

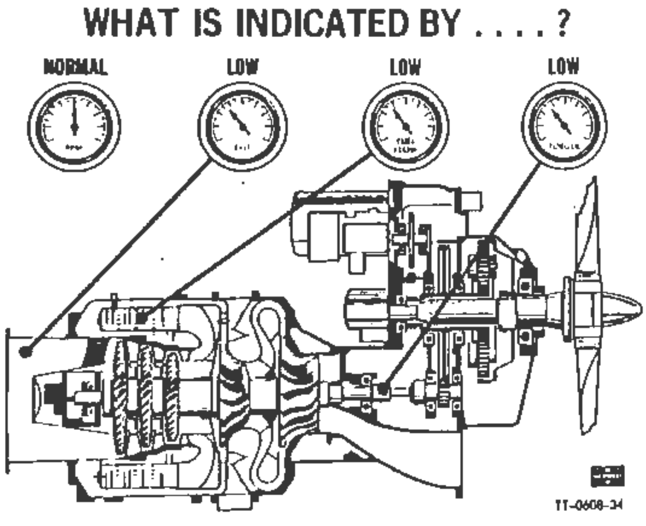
Effective troubleshooting of the fuel system requires that the maintenance mechanic analyze the symptoms, locate the problem and take corrective action with a minimum amount of time and cost. This list identifies some of the assistance available to the mechanic. There are troubleshooting charts and procedures in the maintenance manual that can assist the mechanic in analyzing the symptoms.

Secondly, the mechanic should never overlook the indications in the cockpit. This includes pilot complaints as well as indications that the mechanic can see for himself during a flight. These may involve things that cannot be duplicated on the ground, such as sink rate, or asymmetrical thrust under matched power lever conditions.

Identification of a particular problem area can certainly be made easier by having test equipment and knowing how to use it.

When the trained mechanic who uses these aids also has a complete understanding of the system, troubleshooting becomes a matter of simple logic, a step-by-step procedure involving minimum time and cost.

The result of many years of experience by the engineers and service technicians is assembled in troubleshooting charts in the engine manual. The procedure for using these charts will be described in detail in the final section of this book. Mechanics should be aware of the presence of these charts. With them, he can compare the symptoms seen on a problem engine to the charts and find the recommended corrective action.

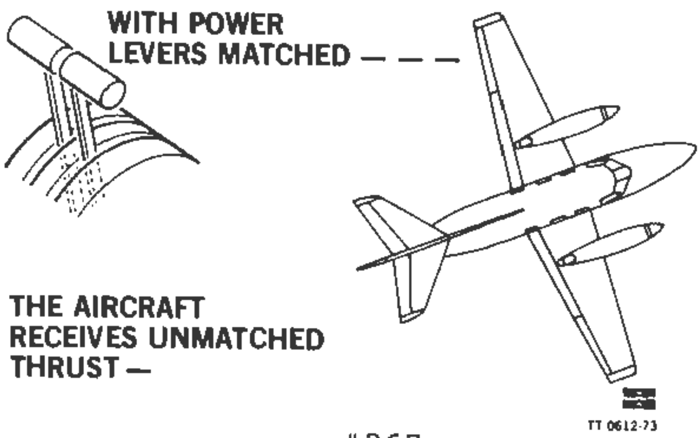


#266

This illustration represents a typical example of the valuable information a troubleshooting mechanic can receive from the cockpit engine instrumentation. This may be as reported by the pilot, or can be a result of the engine being operated on the ground by the mechanic.

These engine instruments reflect a normal engine rpm with a lower than normal fuel flow, EGT, and torque. If the operator were attempting to make takeoff power and saw this set of indications, it is obvious that the problem would be one of being fuel limited. The ability to recognize this problem from the cockpit certainly reduces the time that the mechanic might spend in deciding what course of action he should take.

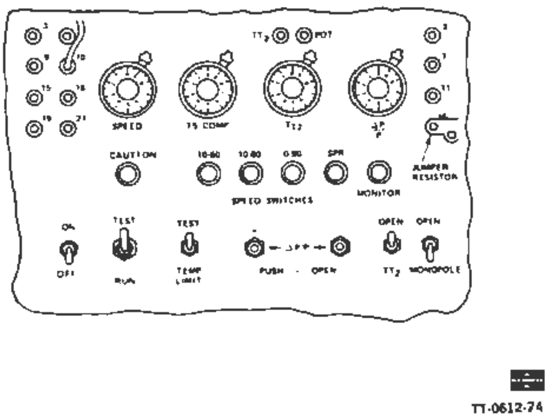
AIRCRAFT PERFORMANCE



#267

An accurate description of aircraft performance during flight, when problems exist, can be a valuable piece of information for the troubleshooting mechanic. In the sample illustrated, the pilot may complain that when the power levers are matched during flight, the aircraft obviously receives an asymmetrical thrust condition which results in a yaw of the aircraft. It may be very difficult sometimes to simulate these problem conditions on the ground during the course of maintenance investigation. Good communication with the pilot, therefore, is important.

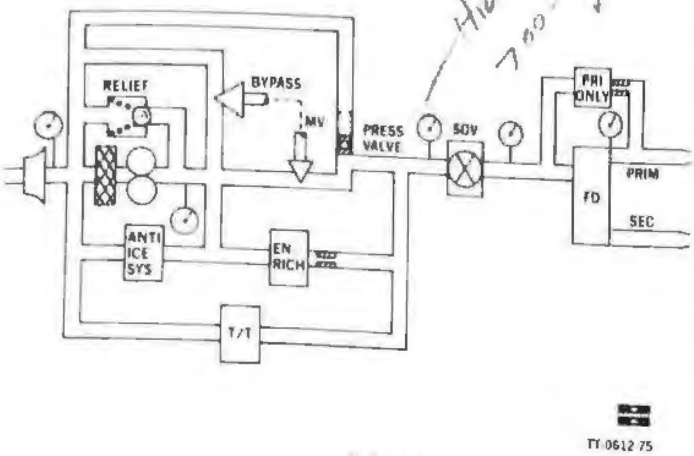
SPEED SWITCH CHECK



#269

Shown here is a portion of the test panel on the -10 Engine tester. As an indication of one of the many tests that can be accomplished with this equipment, note the series of lights in the center of the panel, identified as "Speed Switches." When this tester is properly connected to the engine system, these test lights will indicate operation of the speed switches in the auto start computer. If you were troubleshooting a problem in which the engine would not lightoff at 10%, this light indication might tell you that no power is being received to the fuel shutoff valve at 10% because the speed switch is not closing. Test equipment such as this can be very useful in the hands of a trained mechanic.

PRESSURE TEST POINTS



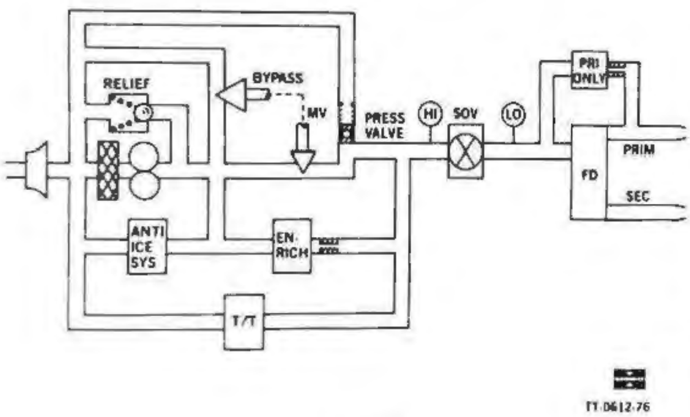
#270

Even the mechanic who does not have ready access to the test equipment can still obtain troubleshooting information by the use of simple pressure gages. This illustration identifies a number of places where gages can be conveniently connected.

Starting at the left of the picture, the aircraft system provides a pressure indication to either a gage or a low pressure warning light. Downstream of the high pressure pump, there are a number of places indicated on this drawing where a pressure gage can be connected.

Problems that may occur in a fuel system usually fall into one of two categories. There is either an undue restriction somewhere in the system, or there is a leak. Let's see how these can be located by the use of pressure gages.

FUEL SYSTEM RESTRICTION



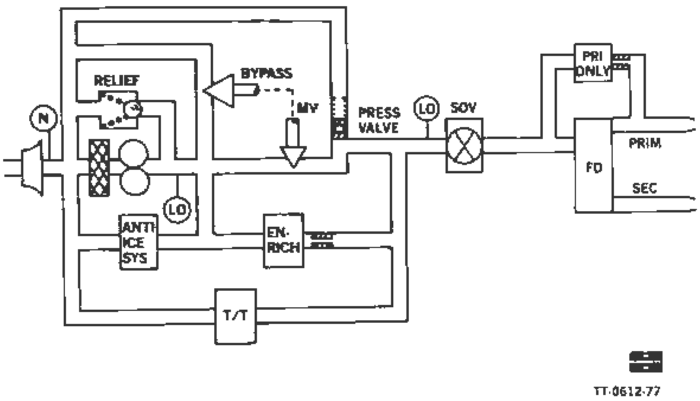
#271

The ability to recognize an abnormal pressure indication in the fuel system is, of course, dependent upon experience and/or recorded data so that the mechanic knows what the normal indications should be. Remember that the pressure in the fuel system varies with the position of the power lever. Mechanics should take advantage of every opportunity to record what pressures are normal at any point in a system when the engine is operating properly. This kind of information can be extremely helpful later when troubleshooting.

In this particular installation, a gage is installed upstream of the shutoff valve registering a higher than normal pressure.

The gage downstream of the shutoff valve is registering a lower than normal pressure. This obviously indicates a restriction at that point between the high and low pressures. This same principle could apply across any component in the system, for example, if pump discharge pressure was higher than normal, but fuel control discharge was lower than normal, it could indicate a problem within the fuel control.

INTERNAL LEAK
ENGINE AT CRANKING SPEED WITH S.O.V. CLOSED



#272

Assume that a failure to lightoff indicated a fuel limiting problem. A gage would first be installed at that point in the system most easily accessible. In this case, we have put a pressure gage upstream of the fuel shutoff valve and it indicated lower than normal. We might consider that this indicated a restriction upstream of that point, so we moved the gage up to pump discharge pressure and found that it was also lower than normal. The boost system from the aircraft indicates that a normal supply of fuel is being provided to the engine. Our immediate reaction may be that the pump is bad and it's possible that this is true. However, before we attempt an expensive pump change, let's consider that this indication may also be the result of a leak. Remember, a positive displacement pump, pumping a given volume, will result in a pressure as a function of the resistance to that flow. If we have a leak, we may be pumping a normal volume, but we will not build up pressure because of the lack of resistance to flow.

An external leak is very easy to find because you usually start with the fuel that's on the ramp and find out where it came from. An internal leak--on the other hand--is a little more difficult to locate. If there is an internal leak in the system, it has to be getting back to the inlet side of the pump. The logical thought process can be aided considerably by the use of a simple schematic.

It becomes a very simple matter to start at the inlet side of the pump, and backtrack to find out where it may be coming from. For example, the top line in this schematic is a bypass back to the inlet side of the pump from the pressurizing valve. If there is internal leakage at the "O" ring, the fuel would be allowed to get back to the inlet side of the pump. A relief valve may have a foreign object holding the ball off the seat. If the torque temperature limiter has a leak, it would allow fuel back to the inlet side of the pump. If the items in this system that are readily available to the mechanic check out positive, he may then get to the point of replacing the pump, or even the fuel control. It certainly warrants this type of troubleshooting analysis before getting involved in the expense of the major component change.

SUBJECT:
SECTION 7 - FUEL SYSTEM

WORKBOOK EXERCISE 5

1. Engine driven fuel pump discharge pressure would reach its highest value during normal engine operating conditions when:

   a. The engine stop switch energizes the fuel shutoff valve closed.
   b. The engine is accelerating between 30 to 60% rpm.
   c. The engine is producing takeoff power.
   d. The engine is producing full reverse power during aircraft landing.

2. A positive displacement pump that will pump .005 lbs. of fuel per revolution would pump how many PPH at 4,500 rpm?

   a. 135 PPH
   b. 22.5 PPH
   c. 225 PPH
   d. 1,350 PPH

A certain operator had been using JP 5 fuel. During an emergency use of AV/gas, he had changed the specific gravity adjustment six clicks clockwise on the fuel control. When he returned to the use of JP 5, he forgot to return the adjustment to the correct setting.

3. The flow of the JP 5 at any given position of the power lever from flight idle to maximum would be:

   a. Lower than normal.
   b. Higher than normal.
   c. Normal.

4. Could the improper setting of specific gravity, as described above, affect the sink rate of the aircraft during landing when the power lever is at flight idle?

   a. Yes.
   b. No.

5. The rate of descent would be:

   a. Higher than normal.
   b. Less than normal.
   c. Normal.

6. A hole in the fuel control bellophragm diaphragm would result in:
   a. Normal acceleration rate and EGT.
   b. A reduction in the rate of acceleration and higher than normal EGT.
   c. The engine acceleration up to the overspeed governor setting.
   d. A reduction in the rate of acceleration and lower than normal EGT.

7. If an engine start is attempted with the speed lever in the high rpm (takeoff) position:
   a. The turbine temperature will exceed the start limit of 770°C EGT during acceleration.
   b. The underspeed governor will stop engine acceleration at the normal low taxi rpm.
   c. The high engine speed will produce too much forward thrust and the aircraft may jump the chocks.
   d. Normal acceleration will be stopped at approximately 97% rpm.

8. During a maximum power ground check of the engine, the P3 plumbing to the fuel control came loose and caused the bellophragm to sense atmospheric pressure. The engine would:
   a. Continue to operate normally until the next engine start was attempted.
   b. Accelerate to the overspeed governor setting.
   c. Immediately lose power due to a drop in fuel flow.
   d. Immediately exceed the torque or EGT limit.

9. Assume that the overspeed governor had been improperly adjusted to 100%. Operation of the engine with the speed lever at takeoff rpm would be:
   a. Normal in prop governing mode but fuel limited in beta.
   b. Normal in beta mode but fuel limited in prop governing.
   c. Fuel limited in beta and prop governing modes.
   d. Normal in beta and prop governing but would be abnormally slow in rate of acceleration during the start cycle.

WORKBOOK EXERCISE 5

10. The auto/start computer automatic control of fuel enrichment is effective:

a. Between 10 to 80% rpm and up to 695°C EGT.
b. Between 10 to 60% rpm and up to 695°C EGT.
c. Between 10 to 60% rpm and up to 770°C EGT.
d. Between 60 to 80% rpm and up to 770°C for 1 second maximum.

11. If the 24 VDC power to the fuel shutoff valve was interrupted during flight, the engine would:

a. Continue normal operation.
b. Reduce power due to limited fuel.
c. Feather the propeller.
d. Operate at the overspeed governor setting.

12. The fuel flow required to provide the calibrated differential pressure needed to open the flow divider will be:

a. Lower with the "primaries only" solenoid valve open.
b. Higher with the "primaries only" solenoid valve closed.
c. The same with the "primaries only" solenoid valve open or closed.
d. Higher with the "primaries only" solenoid valve open.

13. During a flight test to verify flight idle fuel flow adjustments, the aircraft is found to have a high sink rate and yaws to the left. This would be caused by:

a. Higher thrust than normal from the left engine.
b. Higher thrust than normal from the right engine.
c. Lower thrust than normal from the left engine.
d. Lower thrust than normal from the right engine.

14. After making a flight idle fuel flow adjustment, you should check and readjust as required:

a. The USG high setting.
b. The maximum power fuel flow adjustment.
c. The prop governor high setting.
d. The flight idle blade angle.

WORKBOOK EXERCISE 5

15. The specific gravity, flight idle fuel flow, and maximum power fuel flow adjustments should be accomplished in what order?

    a. Maximum power, flight idle, then specific gravity.
    b. Specific gravity, flight idle, then maximum power.
    c. Specific gravity, maximum power, then flight idle.

SG

Problem statement: Fuel limited.
Troubleshooting information: When the engine is cranked above 16% rpm with the fuel shutoff valve mechanically closed, upstream pressure is normal - but, with the valve open, upstream pressure is low.

16. The problem would most likely be caused by:

    a. Restricted primary nozzles.
    b. The torque/temperature limiter bypass valve open.
    c. Restriction in the fuel shutoff valve.
    d. Incorrect operation of the bypass valve within the FCU.

Problem statement: Fuel limited.
Troubleshooting information: The results of an alternate nozzle check place the intersect point to the right of the line. It was also noted from additional gage readings that primary and secondary manifold pressures are higher than normal.

17. The problem would most likely be caused by:

    a. Restricted fuel atomizers.
    b. Restricted flow divider inlet filter.
    c. Pump discharge pressure too high.
    d. The flow divider failing to open.

Problem statement: Fuel limited.
Troubleshooting information: Test gages indicate flow divider inlet pressure and primary manifold pressure to be higher than normal, and secondary manifold pressure to be lower than normal.

18. The problem would most likely be caused by:

    a. Restricted primary nozzles.
    b. Restricted secondary nozzles.
    c. The flow divider not opening properly.
    d. A secondary nozzle tip missing.

SECTION EIGHT:

EGT INDICATION SYSTEM

WHY EGT INDICATION?

TPE 331 POWER IS LIMITED BY:

- TORQUE LIMIT AS DESCRIBED IN SECTION NINE
- TURBINE TEMPERATURE LIMITS AS DETERMINED BY THE ENGINE MANUFACTURER AS A FUNCTION OF MATERIAL, SPEED, ENGINE LIFE, ETC.

PILOT IS REQUIRED TO MONITOR ENGINE POWER WITHIN THESE LIMITS

#276

You will recall that the power taken from the 331 is limited by either a maximum torque or a maximum temperature, whichever comes first. The turbine temperature (or "EGT") indication--one of the most important instruments on the cockpit panel--will be explained in this section. The Torque Indication System will be described in Section Nine.

The torque limit, in a specific application, will be primarily determined by the aircraft manufacturer, based upon structural integrity and aircraft performance. The turbine temperature limit, however, will be determined by the engine manufacturer as a function of the materials being used, the speed that the parts turn, and the desired engine life. It is vital that the pilot monitors engine power to stay within these limits.

TPE331-10 EGT LIMITS

- **START/ACCELERATION PEAK TEMPERATURE:**
  770°C EGT FOR 1 SECOND
- **TAKEOFF/CRUISE MAXIMUM TEMPERATURES:**
  COMPUTER ON/RPM ABOVE 80% = 650°C EGT
  COMPUTER OFF = REFER TO AIRCRAFT MANUALS

#277

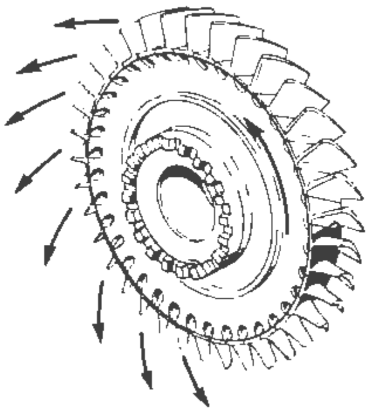
There will be two maximum red lines on your temperature indicating instrument. The first one is involved with the peak temperature reached during start and acceleration. This red line will be marked at 770° Celsius. The temperature limit for start and acceleration is higher than it can be permitted during takeoff and cruise. This is a function of time. During start and acceleration, the engine must be overfueled, resulting in high temperature of the exhaust gases. Due to the short time period involved, these temperatures will not be reflected in actual turbine wheel metal temperature.

When we are ready for takeoff, however, we must observe a different number for EGT limit.

There are two circumstances governing what this number will be. Under normal conditions, the auto start single red line computer will be "ON" and the rpm will be above 80%. Under these conditions, the EGT limit will be 650° Celsius. When the single red line computer is "OFF," and the pilot is operating under manual control, he must refer to the Pilot's Operating Handbook for the specific EGT limit. This will vary with ambient conditions and engine speed. More will be said about this later.

The maintenance manual and the Pilot's Operating Handbooks will indicate a table of limits and the corrective action to be taken if any of these limits are exceeded. Action depends on how much they are exceeded and for how long.

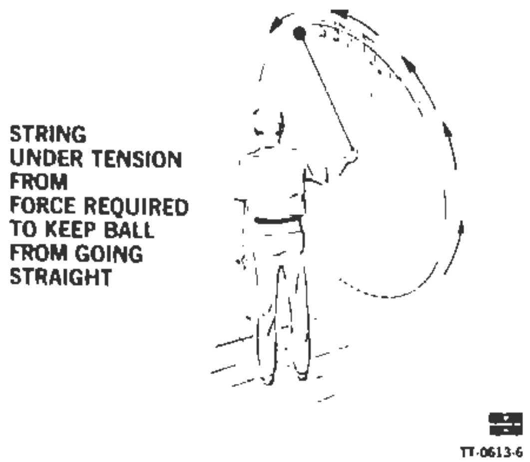
TURBINE BLADES UNDER STRESS


TT-0613-5

#278

We are most concerned with temperature--as far as turbine components go--when considering the turbine wheels in the turbine section. It can be seen from this typical illustration of a turbine wheel that the blades are one piece with the hub. It is obvious that as the turbine turns at high speeds, like 41,730 rpm, the centrifugal force would tend to pull the blades outward. The materials chosen for the wheel must be sufficiently strong to withstand this centrifugal force.

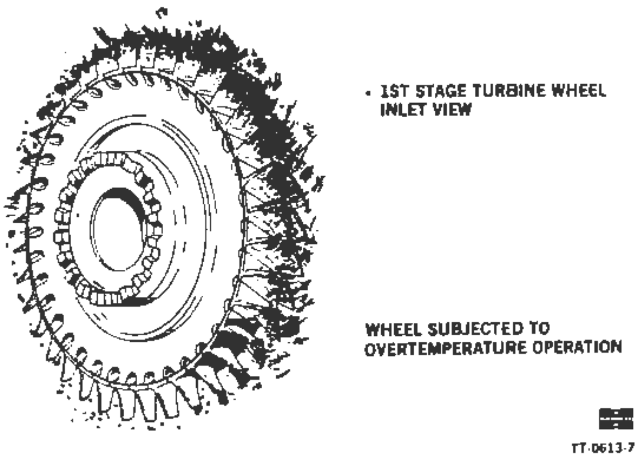
CENTRIFUGAL FORCE



#279

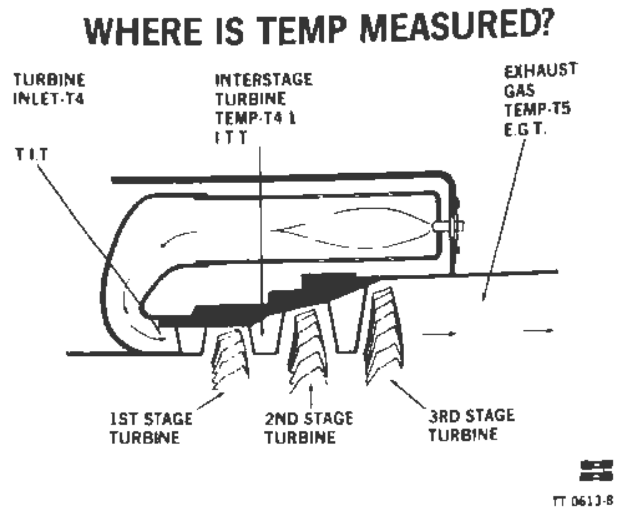
This simple illustration reminds us that under high speed, the tensile strength of the string in this case would be sufficient to keep the ball from flying out in a straight line. The faster the speed, the greater the weight of the ball, and the longer the length of string are all factors contributing to that tensile strength required by the string.

HI SPEED PLUS HI TEMPERATURE



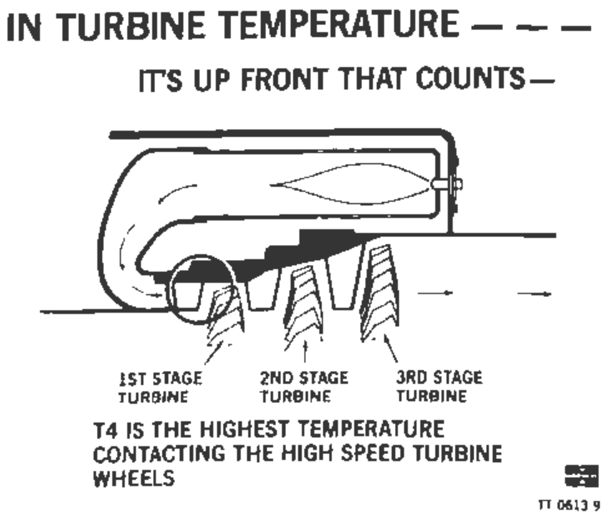
#280

The tensile strength of any material is reduced as temperature increases, and if you get the metal hot enough, it turns to liquid. This illustration portrays the expensive results of subjecting a turbine wheel to a combination of high speed and excessive temperature. The tips of the blades literally fly off as they become overheated. As the blade contours are changed by the removal of material, the efficiency of that wheel is obviously affected. If the first stage turbine wheel was losing metal, it would result in foreign object damage to the second and third stage wheels. Operation under these conditions could result in the replacement of the entire turbine section.



#281

A decision on the specific point in the turbine section where temperature will be measured is made by the airframe manufacturer in conjunction with the engine designer. To review the station locations within the turbine section, turbine inlet, commonly called "TIT" for "Turbine Inlet Temperature," would be at Station T4. "Interstage Turbine Temperature," or "ITT," can also be used. This would be at Station T4.1, at the inlet to the second stage turbine. The exhaust gas temperature, or "EGT," will be measured at T5, downstream of the third stage turbine. Since pressure and temperatures drop across each stage of the turbine, the numbers that will be selected as maximum limits will then be determined by the location of the sensing system. There are a number of considerations involved in making this decision.



#282

This illustration shows us that the first stage turbine wheel would be the point at which the highest temperature would be contacting the high speed turbine wheels. It's this point that really counts in the design of the engine. Should we measure the temperature at this point?

T4 MEASUREMENT PROBLEMS

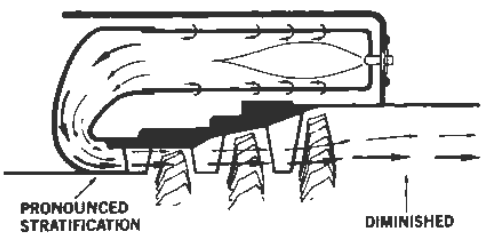
- HIGH TEMP/VELOCITY—SHORT SENSOR LIFE
- AIRFLOW RESTRICTION BY SENSORS
- DIFFICULT MAINTENANCE ACCESS

TT-0613-10

#283

Consider this. Installing temperature sensors at the T4, or turbine inlet temperature position, would create a number of undesirable features. For one, the very high temperature and high velocity of the exhaust gases would result in very short sensor life. Also, the sensors would obviously provide undue restriction and airflow distortion being installed in that very small cross-sectional area. It would also be very difficult to get at them for replacement or repair since the entire hot section would have to be disassembled. This is not desirable because it would increase the cost of operation.

STRATIFICATION



LAYERS OF AIR AT DIFFERENT TEMPERATURE DUE TO VELOCITY AND DENSITY

TT-0613-11

#284

Another disadvantage of attempting to measure turbine temperature at T4 would be the stratification problem. The air density is affected by temperature as the air passes through the transition duct on its way to the turbine. The heavier density air will be thrown to the outside, creating layers of different temperature to be felt at the temperature sensor. Stratification becomes less of a problem downstream in the turbine, after the air has been mixed by the action of the stators and turbines.

I.T.T. (T4.1) IS ONE ALTERNATIVE

- LOWER TEMP AND VELOCITY THAN T4
- HEAVIER PROBE POSSIBLE
- LESS STRATIFICATION
- DIFFICULT MAINTENANCE ACCESS STILL A PROBLEM

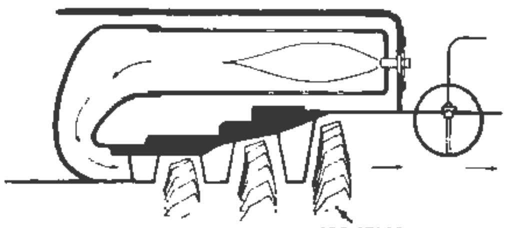
TT-0613-12

#285

One of the possible alternate locations which would help to reduce the T4 problems would be "T4.1" or "Interstage Turbine Temperature." As we can see from the list, some of the problems are reduced. The lower temperature is a result of a drop that takes place across the first stage, and the lower velocity will be less of a problem than it was at T4. There's also room for a slightly larger probe, and stratification is less of a problem since the air has been mixed through the first stage.

Some of the aircraft flying today with TPE331 Engines utilize the ITT indicating system. Maintenance access is still a problem, however, because it is necessary to disassemble the turbine section of the engine to work on the ITT system.

EGT (T5) ALTERNATIVE



- GOOD MIXTURE OF GASES
- LEAST HOSTILE ENVIRONMENT
- HEAVY PROBE CONSTRUCTION
- EASY MAINTENANCE ACCESS

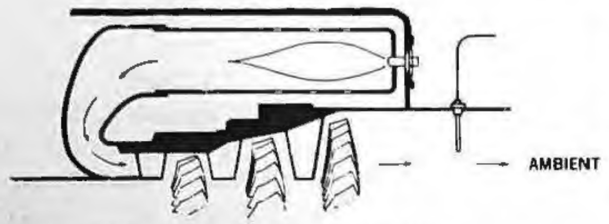
TT-0613-13

#286

The 331-10 Engine models utilize the T5 location for the installation of the temperature sensors. "T5" is the "EGT" or "Exhaust Gas Temperature" identification. The advantages of the T5 location are evident. Good mixture of the gases reduces the effect of stratification. T5 is also the lowest temperature to be found in the turbine section. The probes can be of the heaviest construction, assuring long life and minimum problems. Maintenance accessibility is also excellent. The entire EGT probe system can be removed from the exhaust duct without any disassembly of the engine itself.

The earliest models of the 331 utilize the EGT system. Their reliability has been demonstrated over many hours of operation.

EGT HAS ONE PROBLEM — — —



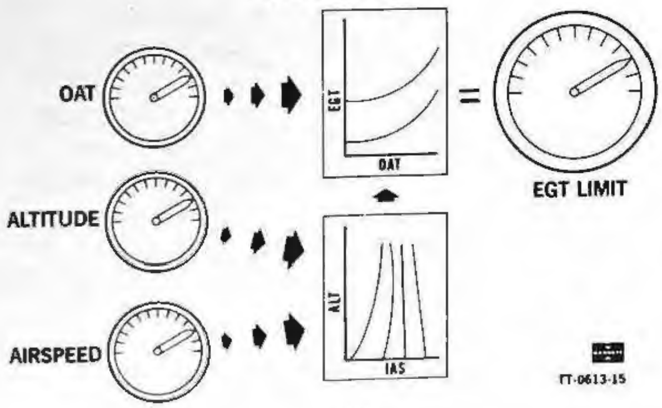
- EGT IS AFFECTED BY AMBIENT CONDITIONS
- PILOT NEEDS TO KNOW WHAT MAXIMUM EGT IS FOR ANY CONDITION OF PRESSURE ALTITUDE, I.A.S. AND O.A.T.

TT-0613-14

#287

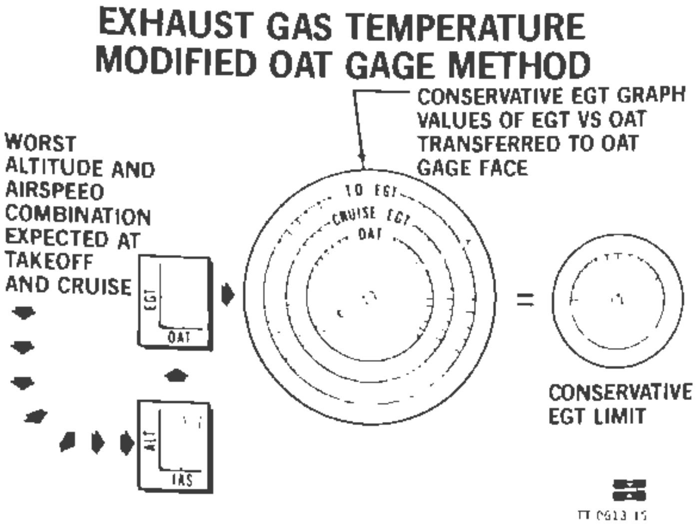
The advantages offered by the T5 position make it the best choice of the three locations. However, one problem must be considered. The location of the EGT sensors in the exhaust duct downstream of the third stage turbine puts the sensors in a position where they are affected by the ambient conditions that exist in the exhaust duct. These ambient conditions of pressure altitude, indicated air speed, and outside air temperature will cause a different EGT number to be representative of the maximum turbine inlet temperature that we must not exceed. In order to minimize the time and effort represented by the pilot's attempt to establish what the EGT limit is, it is necessary that we design a system to do this for him.

EXHAUST GAS TEMPERATURE—GRAPH METHOD



#288

One of the methods used in the earlier 331 Powered Aircraft utilizing EGT is illustrated here. The pilot had a set of curves in his handbook. He could go to those curves representing the altitude and air speed pressure conditions and then go to an outside air temperature gage curve. From these curves, he could then read what the EGT limit would be under those conditions that would represent operating at the maximum turbine inlet temperature.

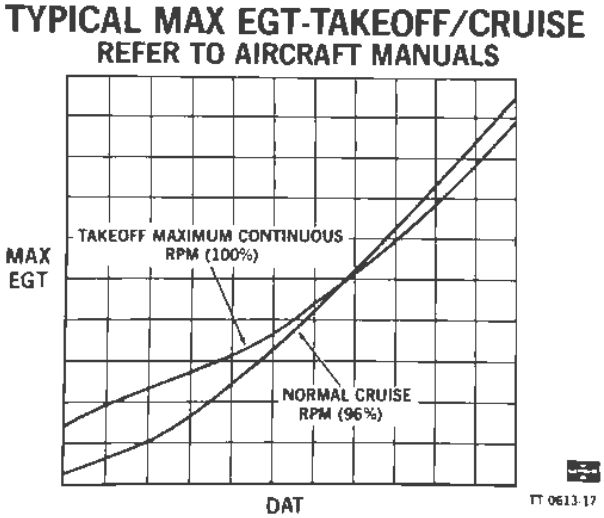


#289

Some aircraft utilizing the EGT system have saved the pilot time by incorporating the information from the curves to the face of the "Outside Air Temperature" or "OAT" gage. The needle extends over the OAT line showing the takeoff and cruise rpm EGT. The pilot can then select a conservative EGT limit from the face of this instrument.

Including this information on the OAT gage does not take the place of an EGT gage. It merely provides a source of reference relating EGT limits to the present ambient condition.

It will be noted that there are two scales, one for takeoff conditions--where the engine is operating at 100 per cent rpm--and another one for cruise EGT--where the engine is operating at 96 per cent rpm. These numbers are different.

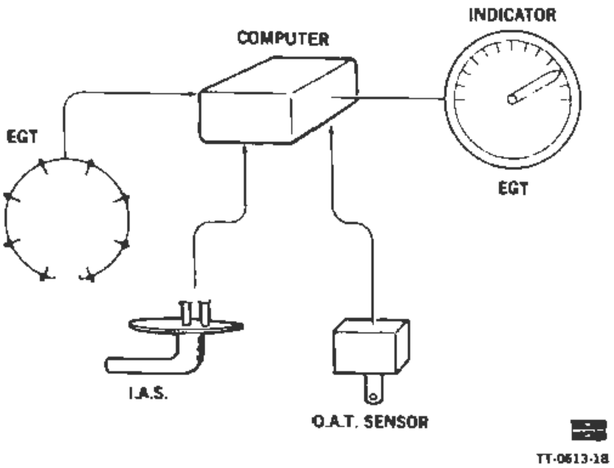


#290

This curve represents typical information that may be found in pilot aircraft manuals. The EGT limit is affected by the various speed conditions of the engine. Again, we are concerned primarily with what happens at T4, the turbine inlet temperature, but as engine speed and airflow conditions change within the combustion section, it will reflect a change in the EGT in order to maintain that same T4 limit. We can see here that when the engine is running at 100 per cent rpm, as it does during takeoff or maximum cruise rpm conditions, one curve represents the EGT limit under those conditions of speed. When we reduce the speed in cruise to 96 per cent rpm, conditions within the engine change.

We must assume a new set of limits for the EGT indication in order not to exceed the TIT Limits. This is typical.

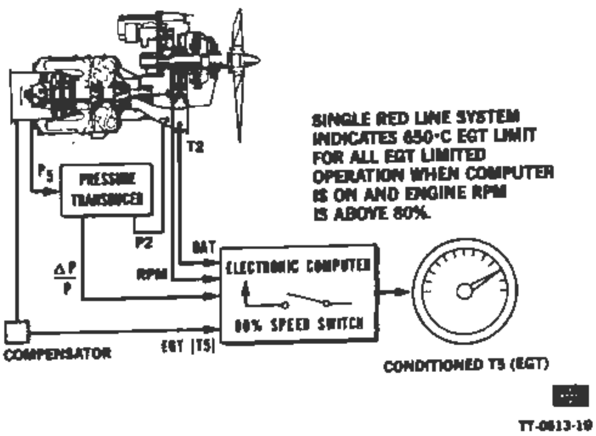
EGT—COMPUTER METHOD



#291

Some 331 Powered Aircraft have used a computer system for many years. Here you can see that the computer receives the EGT signal and a signal from the "Pitot-Static" system that represent pressure altitude and "Indicated Air Speed" (I.A.S.). A signal from an outside air temperature sensor provides the third variable input into the computer. The computer then takes into consideration the effects of these variables on the EGT and presents it to the indicating system as a calculated EGT. This approach is called a "Single Red Line" system and the obvious advantage of the system is that it minimizes the pilot effort necessary to utilize the curves as previously described.

TPE331 SRL SYSTEM



#292

The 331-10 Engines utilize a single red line system that operates whenever the engine is above 80 per cent rpm, and the computer is turned "ON." We can see from this simplified schematic that there are a number of inputs from the engine. There is a temperature signal from the exhaust thermocouple, at the T5 position. The pressure transducer in the center indicates the pressure ratio across the engine measuring P_2 and P_5. This is called a "Delta P Over P Transducer" and it sends the signal to the computer indicating the pressure density effects. Coming from the middle of the engine is a signal representing the speed of the engine.

You will recall this speed signal comes from a monopole within the propeller governor. Finally, there is a sensor in the inlet measuring T_2, or the temperature of the air. This represents the outside air temperature condition put into the computer.

Internally within the computer, is an 80 per cent speed switch. When you are above 80 per cent rpm and that switch is closed, those input signals to the computer will result in a conditioned EGT signal to the aircraft indicating system, allowing the system to be operated to a fixed limit value of 650° Celsius under any cruise speed conditions from 96 to 100 per cent rpm. The next sequence of illustrations will explain this system and its individual components.

TPE331-10 SYSTEM COMPONENTS

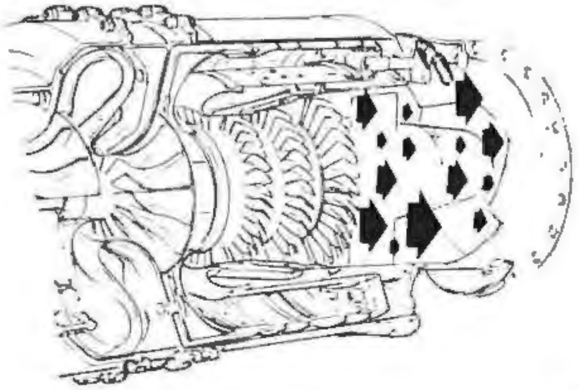
- THERMOCOUPLE HARNESS
- COMPENSATOR
- $\Delta P/P$ TRANSDUCER
- T_2 SENSOR
- RPM MONOPOLE - PROP GOVERNOR
- SRL/AUTO START COMPUTER
- AIRCRAFT INDICATOR

#293

Not all of the components in the single red line indicating system are part of the engine. However, the entire system will be discussed, including the aircraft indicating system. This will make it easier for the mechanic to relate the operation of the entire system.

This list indicates the sequence in which these components will be described: the thermocouple harness, compensator, Delta P over P Transducer, T_2 sensor, rpm signal, the computer and aircraft EGT indicator.

WHAT IS THE "AVERAGE" EGT?



#294

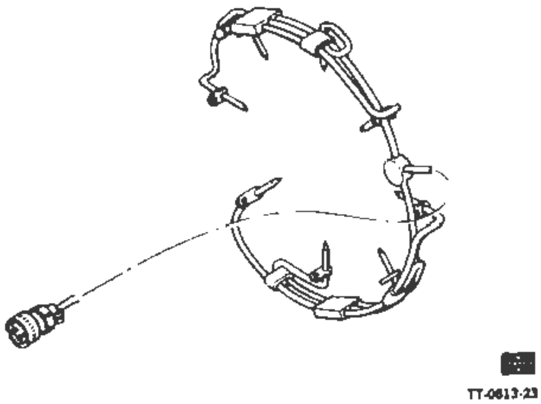
One of the important considerations in installing temperature sensors in the exhaust duct is the fact that we must still consider the stratification, or temperature layers of the air, that may exist. It is true that the stratification is diminished after passing through the three stages of turbine, but it can still be a problem to determine what the average temperature is.

SYSTEM CONTROLS TO AVERAGE EGT

#295

This cartoon illustrates the problem of stratification. Our stupid young friend may think he's comfortable, but you can bet he would have a difficult time convincing his feet of that.

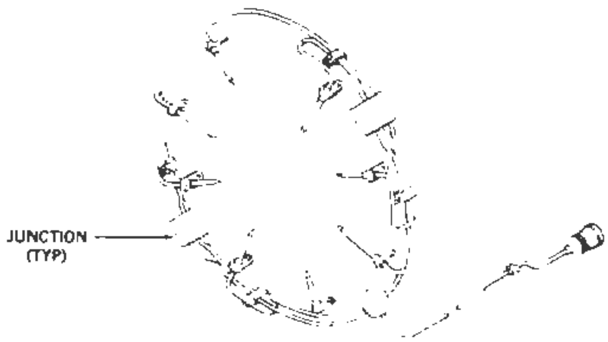
TYPICAL AVERAGING THERMOCOUPLE RAKE



#296

This illustration identifies that the thermocouple rake, sometimes called "Thermocouple Harness," includes eight separate thermocouples that will sense the temperature at eight different points. The signal is averaged as it is sent through the electrical connector to the system.

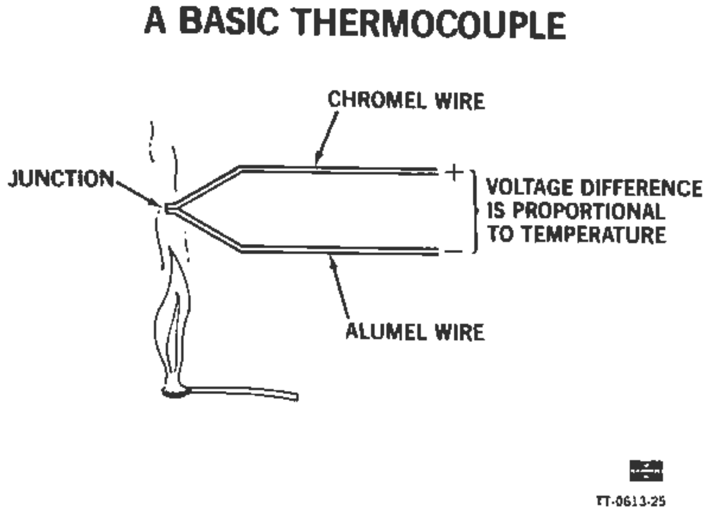
AVERAGING THERMOCOUPLES
MULTIPLE PROBES OF DIFFERENT LENGTHS



IDENTICAL RESISTANCE FROM EACH PROBE TO OUTPUT

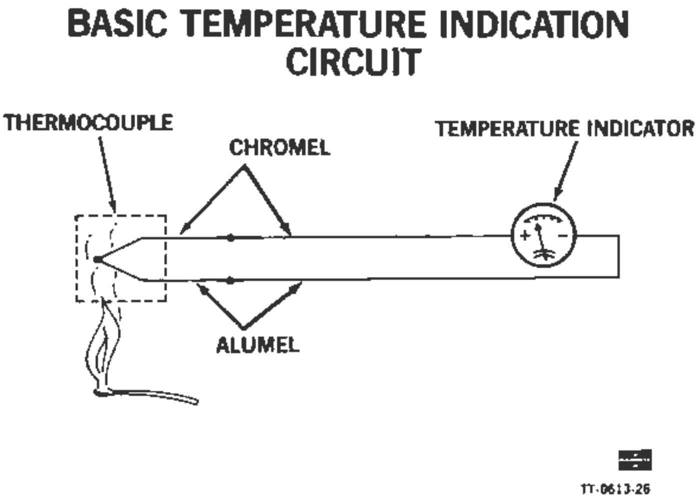
#297

Here you can see that the probes are of different lengths. This results in the measuring point in the thermocouple probe extending into different layers of stratified temperatures. Notice that the dimension of the wiring from each thermocouple is the same to each junction. This is necessary so that the same resistance will be in each leg of the circuit. This results in an averaging signal being sent from the thermocouple harness. The eight-probe thermocouple harness is a sealed unit properly insulating all of the individual wiring.



#298

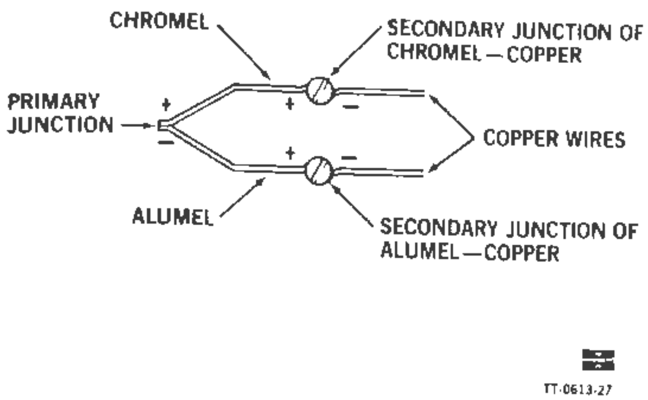
This drawing reminds us that a thermocouple is nothing but a joining of two dissimilar materials. In this case, chromel wire is joined at the tip with alumel wire. When temperature increases at the junction, a voltage differential is created and a current flow is induced into the wiring system. That voltage differential is proportional to the change in temperature. We can thus, utilize this principle in the temperature indicating system.



#299

This simple drawing helps illustrate the principle of the temperature indicating system. The voltage differential created by a temperature change measured at the thermocouple can be utilized in a simple instrument reflecting the current flow. This device, called an "Ammeter," is calibrated in degrees of temperature.

SECONDARY THERMOCOUPLE EFFECT

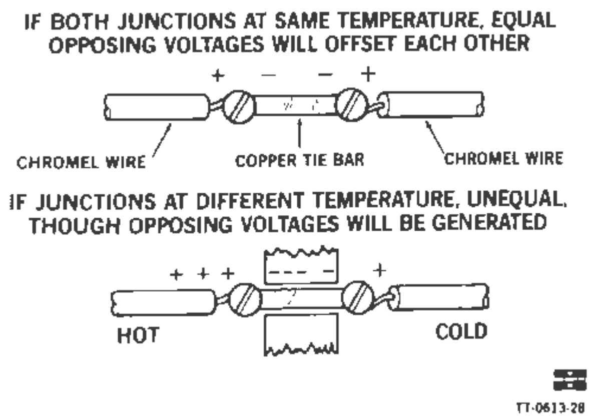


#300

Later in this section simple maintenance actions will be discussed involving checking resistance and insulation of the EGT thermocouple assembly. However, it should be pointed out at this time that as we deliberately create a thermocouple by joining two dissimilar metals, we may also unintentionally create undesirable thermocouples by the same principle. These undesirable thermocouples are referred to as "Secondary Thermocouples."

You can see in this illustration, that the primary junction is a joint of chromel and alumel. If those wires came back to a connection where they were joined with copper, we would have then formed another thermocouple at the chromel-copper joint, and at the alumel-copper joint. If these thermocouples are subjected to temperature changes, they can affect the voltage being felt in the indicator.

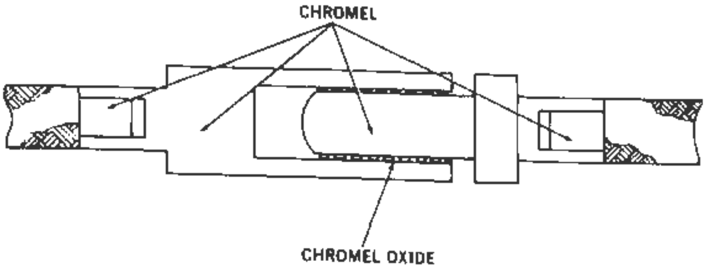
SECONDARY EFFECTS MAY, OR MAY NOT, CANCEL



#301

The top picture in this illustration identifies the chromel wire attached to copper. The copper is then attached to a chromel. If both of these junctions feel the same temperature, they will create an equal, but opposing voltage, offsetting each other and having no substantial effect on the reading at the indicator. However, the lower drawing illustrates the possibility of these junctions being on either side of some insulation. If the junction on the left sensed a different temperature than the junction on the right, unequal voltages would be created and could affect the voltage sensed to the indicating system.

CORROSION EFFECT
ELECTRICAL CONNECTOR CORROSION



CHROMEL TO OXIDE = SECONDARY THERMOCOUPLE

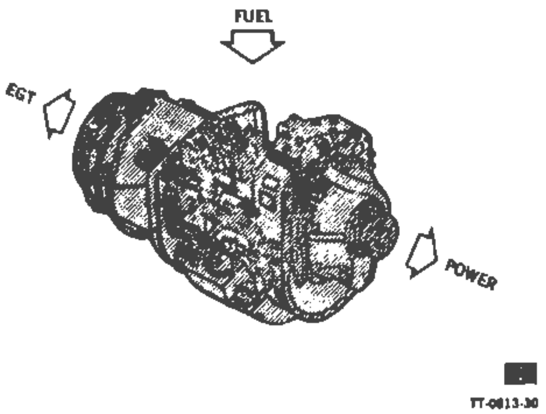
TT 0613-29

#302

One of the more common secondary thermocouples that may be found in temperature indicating systems is created by corrosion that may occur in electrical connectors. This illustration is an expanded view of a single pin in a typical electrical connector. Notice that it is chromel to chromel. If corrosion is allowed to occur in male and female pins, the oxidation creates a chromel oxide, which, in effect, becomes a dissimilar metal. If this electrical connector were located in the engine nacelle and was subjected to the cold temperatures of high altitude flight, it might well be responsible for an improper reading on the temperature indicator in the cockpit.

The mechanic may suspect a secondary thermocouple effect if the pilot complains of having to continually mismatch power levers as he changes altitude conditions in order to maintain matched temperature gages. In addition to visual inspection, there is a very simple check utilizing a small can of freon. During a ground check without the engine operating, but with electrical power to the indicating system, the temperature should be observed while the mechanic sprays the freon on the various connection points in the EGT electrical system. If the application of the freon, which has a very high rate of evaporation and a cooling effect, causes a change in the indicator reading, you have undoubtedly located the point where there is a secondary thermocouple. It is good maintenance practice to maintain clean and tight connections in the temperature indicating electrical circuitry.

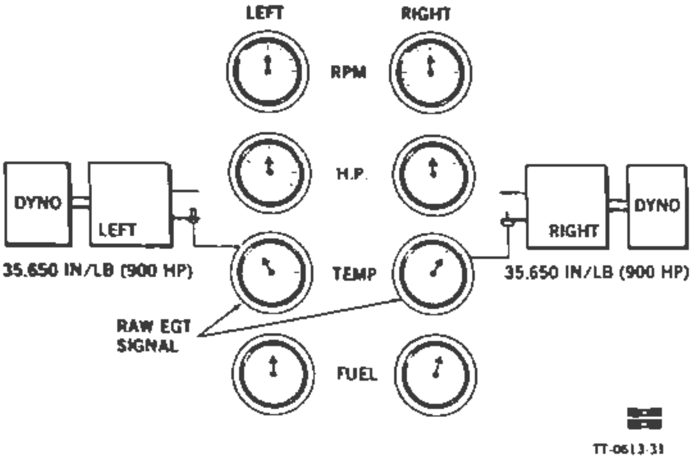
CONVERSION EFFICIENCY = EGT



#303

You learned in the Theory of Operation section that the 331 Engine is an energy converter. It converts the fuel energy into useful shaft horsepower, and the exhaust heat energy measured as EGT. No two engines are absolutely identical in their efficiencies, even though both of them will meet the specifications. This can be a matter of acceptable differences in tolerances and efficiencies of compressors, turbines, and so forth. This means that even with two good engines producing the same power, one engine may require slightly more or less fuel resulting in different EGT between the engines. The Pilot's Handbook gives him one fixed number as a maximum temperature limit. It would be very difficult for him to fly if he had to consider that each engine had its own limit. This necessitates some means of compensating the EGT system to reflect similar temperature indications when engines are producing rated horsepower.

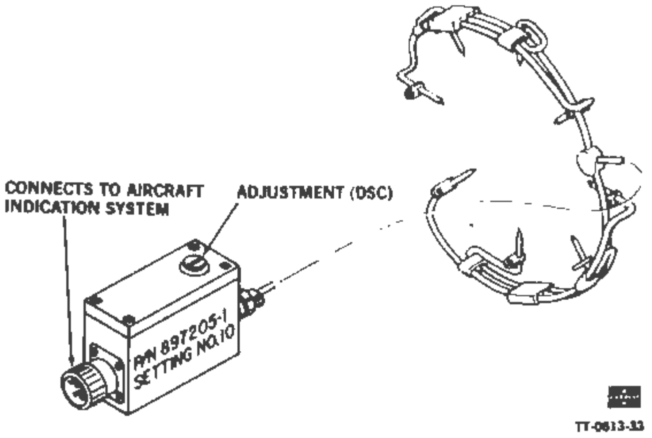
NEED FOR COMPENSATION



#304

To illustrate the point of engine efficiencies as selected by EGT, assume that we removed the left and right engines from your aircraft, and mounted them on dynamometers in the test cells at Garrett. "Dynamometers" are precise load measuring devices that will indicate the exact horsepower being produced. Both engines are mounted on dynamometers and are being run to produce 35,650 inch/pounds of torque, which is 900 horsepower at the shaft rpm of 1591. The right engine is burning a given amount of fuel resulting in a given reading of EGT. These readings are within specifications and the engine is a good one. However, if we look at the left engine operating in the test cell right next to it, this engine is slightly more efficient. It burns less fuel resulting in a lower raw EGT signal. This would be an impossible operating situation. The Pilot's Operating Handbook gives him a maximum temperature limit of 650° Celsius EGT, and this applies to all of his engines. So it becomes obvious that some compensation needs to be done at the engine test cell, so that each engine will indicate the same EGT when both engines are producing the same rated power.

EGT COMPENSATOR



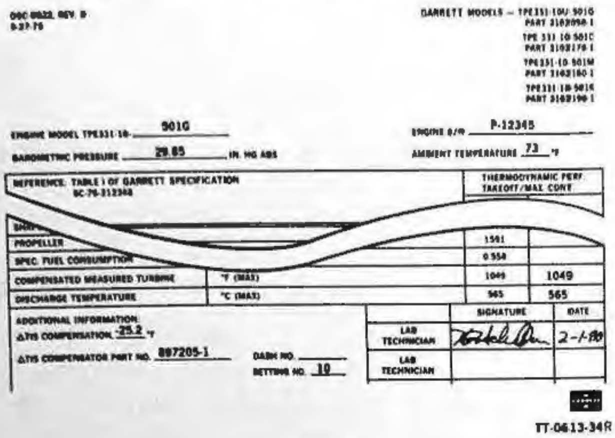
#306

On a typical 331 Engine, if you trace the small tubing coming forward from the harness, you will find that it ends in an electrical connector attached to a rectangular shaped object. This is the "Temperature Compensator." The compensator and the EGT harness come as part of the engine. Attached to the other end of the compensator will be the aircraft temperature indicating electrical system and its components. Whenever the engine is removed from an aircraft, the compensator must stay with the EGT harness and the engine on which it was originally installed. The EGT harness connector is attached to the right side of the compensator. It is a two pin connector. A four pin connector is on the other side of the compensator that attaches to the aircraft system.

Notice the part and setting number on the side of the compensator. This indicates the correct part number and its adjusted value as a correction to the raw EGT signal for this particular engine. The adjustment is located underneath the screw shown on top. This adjustment is made at the factory in the test cell and is sealed with a drop of Glyptol once the adjustment is made. The value of that adjustment will be indicated on the "DSC," or Data Sheet for the Customer, that comes with the engine. It should be included in your engine log book records.

If it becomes necessary during corrective action of an EGT problem to replace the compensator, it must be replaced with a compensator of identical part and setting number.

EGT-FACTORY COMPENSATION



#307

This is a sample of a typical DSC, or data sheet for the customer, that is provided with each engine as it's shipped. On the bottom of this sheet, you can see the information that relates to the EGT indicating system. For example, compensator part number 897205-1, with a setting number 10, will give this system minus 25.2 degrees Fahrenheit correction, often referred to as "Temperature Offset." Just above that information, you can see that the compensated temperature is given in both Fahrenheit and Celsius values. These numbers are the specification value to which the system must be calibrated at the time when the engine is producing its rated power at standard corrected sea level conditions. This data sheet should be retained with the engine log book for reference by the maintenance mechanic.

EGT COMPENSATOR SETTINGS

P/N 897205-2 COMPENSATOR PROVIDES A NEGATIVE OFFSET.

SETTING NO.	MILLIVOLT OUTPUT ± .020 mv	TEMPERATURE OFFSET VALUE -°F	-°C
1	.0	0	0
2	.066	2	1.1
3	.132	6	3.3

P/N 897069 COMPENSATOR PROVIDES A POSITIVE OFFSET.

SETTING NO.	MILLIVOLT OUTPUT ± .020 mv	TEMPERATURE OFFSET VALUE +°F	+°C
1	.0	0	0
2	.066	2	1.1
3	.132	6	3.3

TT 0613-35

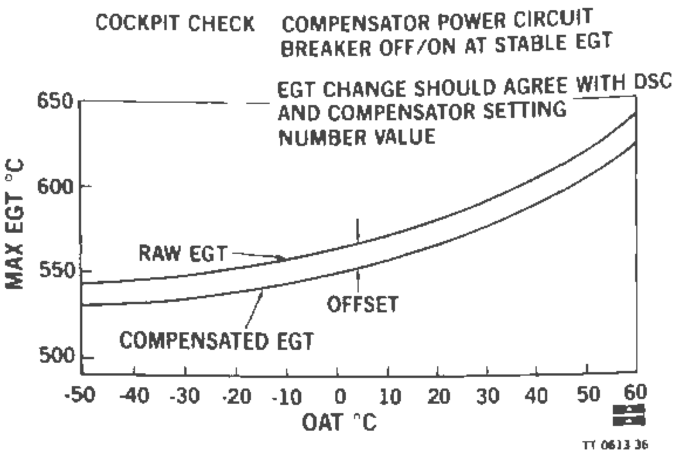
#308

These partial charts are taken directly from pages in the maintenance manual. They indicate that two different part numbers are involved in producing either a negative or positive offset to the raw EGT temperature signal. The millivolt output signal produced by the compensator is used to test the compensator in the shop according to maintenance manual procedure. These charts also indicate the temperature offset value for each of these setting numbers given both in Fahrenheit and Celsius. (Note: To convert °F to °C offset, the formula is: $\frac{°F}{1.8} = °C$).

The top chart deals with compensators that provide a "Negative" offset.

The chart on the bottom of the page gives the same information for compensators that provide a "positive" offset.

EGT COMPENSATOR OFFSET



#309

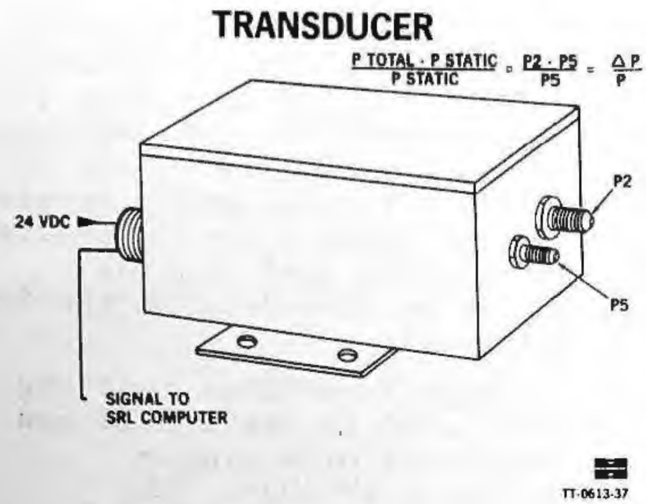
Since the compensator used on the -10 Engine is powered by 24 volts dc, a simple cockpit check using the compensator circuit breaker can verify correct operation of the compensator.

Assume that you have the engine running with the speed levers at high rpm and power at some point less than temperature and torque limits. Allow the engine to stabilize at that EGT condition, pull the circuit breaker and note the change in degrees on the temperature indicator. The increasing or decreasing change should be compared to the offset specified on the data sheet.

You should also check that the part number and setting on the compensator installed on the engine, agree with the information provided on the data sheet.

The curve on this illustration identifies the offset as the difference between the raw EGT signal and the compensated EGT signal. This check can be made at any ambient temperature condition, since the offset is linear in nature.

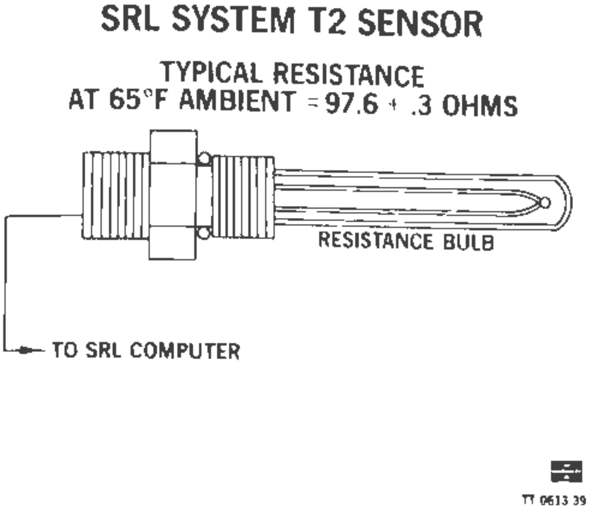
To review, the raw EGT signal is the uncorrected signal from the thermocouple. The compensated EGT signal is that signal adjusted by the engine manufacturer to produce the correct temperature indication when the engines are producing rated power. It can now be seen, that with the compensated EGT signal, the pilot can operate both engines to the same temperature limits.



#310

The next component in the EGT system that puts out a signal to the single red line computer, is the Delta P Over P Transducer. The term, "Delta P Over P," is derived from the formula near the top of the picture: the total pressure minus the static pressure, divided by the static pressure--symbolized as P_2 minus P_5 divided by P_5--equals the delta pressure divided by the pressure. This control is mounted remotely in the nacelle area.

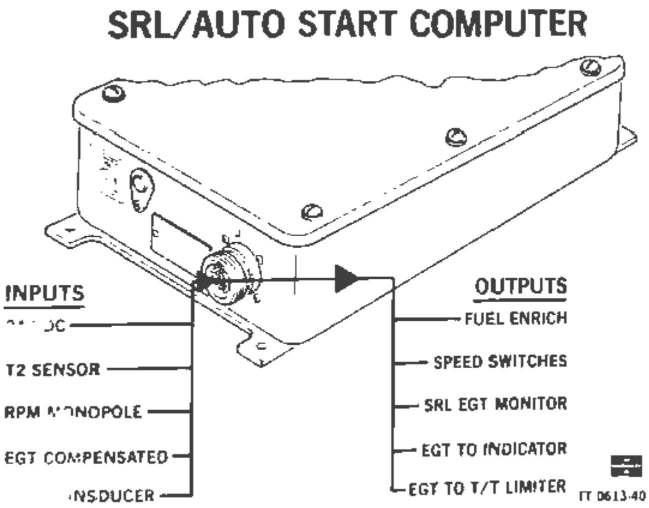
On the right hand side of the box, there are two different size fittings so that connections will not be confused. The smaller of the two fittings connects to the exhaust duct assembly to measure pressure at Station Five. The larger fitting is connected to the P_2 sensing port that is part of the Woodward fuel control system. Sensing of the inlet pressure compared to the discharge pressure of the engine, essentially measures the pressure ratio across the engine. This is affected by ambient pressure altitude and indicated airspeed condition. This pneumatic signal is converted to an electrical signal from the electrical connector on the left side of the box. That signal is sent to the single red line computer. This control is an example of aircraft mounted equipment, and does not include any external maintenance adjustments.



#312

The next input to the single red line computer is the electrical signal of the air temperature at the compressor inlet. A separate T_2 sensor is installed in the inlet. This is completely separate from the T_2 sensing device utilized in the Woodward fuel control system, as we discussed in the Fuel Control Section.

This artwork identifies that the T_2 sensor used in the single red line system is of a simple resistance, bulb type. The resistance changes as the bulb senses a change in temperature of the inlet air to the compressor. You will see in later calibration checks, that at 65° Fahrenheit ambient air condition, this bulb should provide a resistance of 97.6 plus or minus .3 ohms. Resistance check should be made with appropriate test equipment.



#313

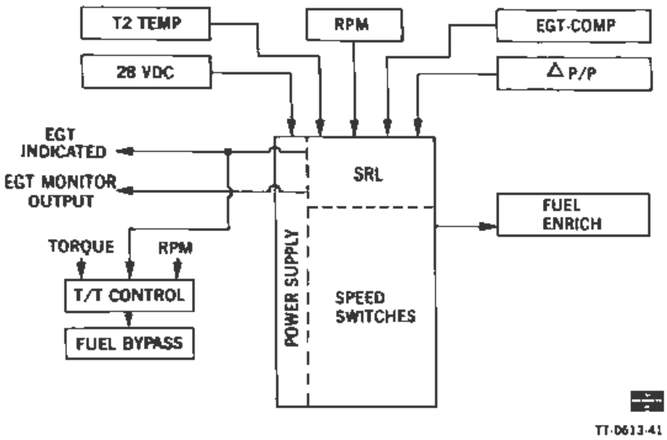
In the discussion about the Fuel System, we made reference to the "Auto Start Computer." It can be seen here, that the auto start computer and the single red line computer functions are included in one control box. It is referred to as the "Single Red Line Auto Start Computer." This illustration depicts the input and output signals to and from the computer.

On the left side, we see the inputs consisting of a 24 volt dc supply, T_2 sensor, engine speed signal from the propeller governor monopole, EGT compensated signal, and a signal of density from the Delta P Over P Transducer.

The outputs from this control are the appropriate signals to the fuel enrichment system, the speed switch signals that provide proper operation of starters, ignition systems, fuel shutoff valves, etc.

A single red line EGT monitoring system will indicate when the EGT is not being corrected to a single red line by the computer, and a conditioned EGT signal to the indicator and torque/temperature limiter is also produced.

SRL COMPUTER



#314

Across the top of this simplified schematic are the inputs to the single red line function: T_2 temperature indication, 28 volt dc power, monopole signal of engine rpm, a compensated EGT signal, and a Delta P Over P Transducer signal. The single red line related outputs, shown on the left side, go to the EGT indicated system, torque/temperature limiter control and to the EGT monitoring system.

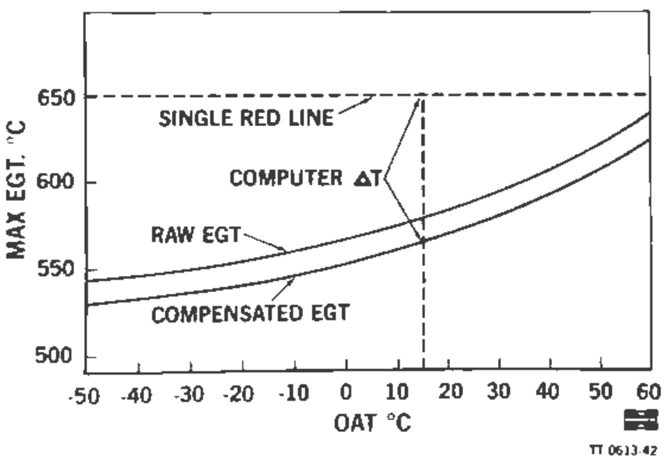
The single red line system will condition the EGT signal to be useable in the single red line system when the computer cockpit switch is "On" and engine speed is above 80% rpm. If the computer power is turned "Off," or the engine speed is below 80% rpm, the signal to the indication system will be compensated EGT only.

The EGT monitoring system output is a signal from the computer that will indicate a warning light when the conditioned EGT is within five Celsius degrees of the compensated EGT. That indication merely warns the pilot that he should be cautious about the use of the single red line 650° Celsius figure.

If the power switch is turned "Off" to the computer because of suspicion that the single red line system is not operating properly, this lack of power will also prevent the auto start functions from occurring. It would be impossible under these conditions to go through a normal start cycle, and expect the speed switches to take care of the fuel enrichment and the proper sequencing of ignition, shutoff, and starter relays.

Some aircraft may incorporate manual backup switches for starting the engine in the event of a complete malfunction of the auto start computer. These switches would provide the ability to manually accomplish the functions of the 10 per cent and 60 per cent speed switches.

SRL COMPUTER ΔT OFFSET



#315

You have already seen a curve very similar to this one, a simple cockpit check of the compensator offset, showing the difference between raw temperature signal and compensated signal. This curve reveals that the "Computer Delta T," or "Computer Offset," is the difference between compensated EGT and the single red line point. At a given stable condition operating on the ground--speed lever at high rpm and power lever at some point less than maximum temperature or torque--turn off the computer power and note the change of temperature indication. This is a simple cockpit check to indicate operation of the SRL system. The specific number of degrees that the indicator changes at the time the computer is turned off should be checked following detailed test equipment instructions.

TYPICAL COMPUTER ΔT TEST

CONDITIONS SIMULATED BY TESTER:

1. ΔP/P SIGNAL = ZERO
2. RPM = 939 Hz (100%)
3. T_2 SENSOR = 97.6 OHMS (65°F)
4. COMPENSATED EGT = 538°C

TURN COMPUTER ON, INDICATED EGT = 620°C

−538

82° OFFSET

COMPUTER ΔT of 82°C IS CORRECT FOR THIS SPECIFIC TEST CONDITION

#316

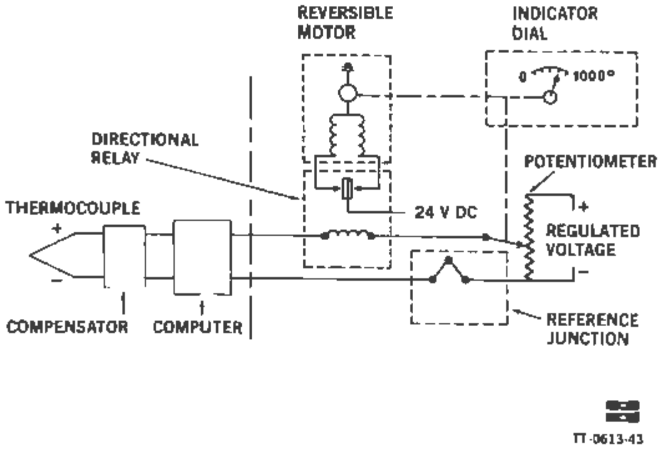
Although the previously described cockpit check can indicate whether the computer is affecting the indicated temperature as the computer's power is turned on and off, it does not specifically check the amount of computer correction under the varying conditions. The maintenance manual procedures will check the differential temperature at various conditions of engine speed and Delta P conditions as simulated by the controls on the tester.

We have taken one test point from the manual for illustrative purposes only. With the test box correctly connected to the computer, the following conditions are simulated by adjusting the potentiometers on the tester panel. Number One: the Delta P Over P will be set at zero, simulating a static condition of the aircraft. Number Two: the speed signal will be simulated by adjusting the potentiometer to indicate 939 HZ. This represents 100 per cent rpm. Number Three: the T_2 sensor potentiometer is adjusted to 97.6 ohms, representing a 65° Fahrenheit ambient condition. Number Four: the input signal representing compensated EGT is established at 538° Celsius.

Under these conditions, when the computer power is turned "On," the indicated EGT would change from 538 to 620 degrees Celsius. This is an offset of 82 degrees. This is the correct offset for this specific test condition. In the maintenance manual procedures, various other conditions will also be tested to represent 98 per cent or 96 per cent rpm cruise conditions and also the Delta P Over P signal changed to indicate flight conditions.

It is a simple procedure to verify the correct single red line function of the computer. Since the computer receives an engine speed signal, the normal single red line limit of 650° Celsius is equally applicable to a 100 per cent cruise or 96 per cent cruise condition. The computer takes care of the calculations as engine speed changes. If the computer single red line system is turned "Off," or is not operating, the pilot must then refer to the aircraft operating instructions, for indications of the appropriate EGT maximums at various cruise speed conditions.

POTENTIOMETER INDICATOR



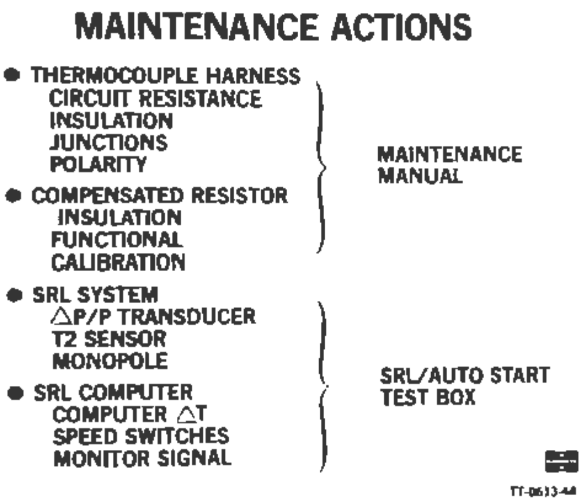
#317

This simplified wiring schematic indicates the basic operation of a potentiometer indicating system. Most modern aircraft utilize the "Potentiometer" system rather than the "Pyrometer" system. The basic advantages of this system are the instant response of a motor driven indicator and the fact that this system is not sensitive to system wiring resistance as the pyrometer systems are.

The potentiometer system operates on a "Null and Balance" principle. When the balance of voltage between the indicating system, and a variable potentiometer is matched, the directional relay receives no signal. Increased voltage from the thermocouple system causes an unbalancing with the potentiometer, and a current flow through the directional relay. The relay positions a contact in a reversible motor, causing the motor to drive the indicator towards a higher reading.

Connected to the indicator is the potentiometer that adjusts the regulated voltage. When the regulated voltage becomes matched to the system input, the instrument stops at that point and the directional relay is again centered. When the voltages are balanced, a null position is reached, and no action is taken by the indicator.

This indicating system is typified by its rapid response moving from point to point without the usual lag experienced in other systems. Maintenance details involving aircraft indicating systems should be obtained from aircraft manuals.

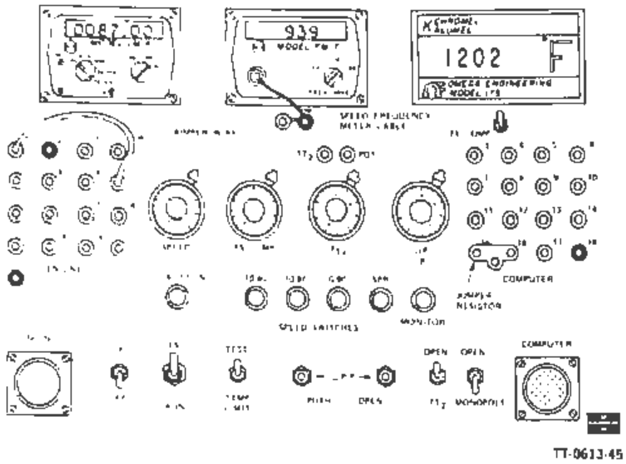


#318

Typical maintenance actions for the EGT indicating system components are shown here. The thermocouple harness can be checked for circuit resistance and insulation of the internal wiring to the external case. Checking the junctions and polarity of the systems is all described in the engine maintenance manual in detail. Most of this can be accomplished with a simple "Ohmmeter," the compensating resistor can also be functionally checked and calibrated. The functional check consists of the cockpit test previously described in which you shut off the compensator power and note the change in temperature indication. The calibration is basically a shop test, requiring appropriate test equipment. The rest of the components in the single red line system, such as the Delta P Over P, T_2 sensor, propeller governor monopole and the computer with its speed switch functions and monitoring signals, can be tested with the test box specifically designed for this purpose.

The instruments and lights on this portable test box can be connected to the engine auto start system computer with leads that are provided with the test kit.

TEST PANEL



#320

The major elements of the test panel are the three instruments across the top. A "Digital Read-Out Voltmeter" on the left, a "Digital Frequency Meter" on the top center, and a "Temperature Indicator" on the upper right.

The four dials in the middle of the panel are four potentiometers where signals can be simulated into the controller. From left to right. the potentiometers can be identified as follows; "Speed Indication," "EGT Compensated Signal," "T_2 Sensor Input" and a simulated signal from the Delta P Over P transducer. Below these potentiometers are a series of lights used to indicate the actuation of the speed switches. The "SPR" light indicates fuel enrichment. The monitoring system light is on the right side.

The jacks on the left are used to connect the instruments to specific components in the engine. The jacks on the right indicate similar type test points within the computer circuit.

Procedures for using this test box in troubleshooting and corrective action with the auto start single red line computer are spelled out in detail in the appropriate manual.

SUBJECT:
SECTION 8 - EGT SYSTEMS

WORKBOOK EXERCISE 6

1. EGT limit during start/acceleration of the 331-10 engine is:

   a. 650°C.
   b. 695°C.
   c. 770°C.
   d. 770°C/1 second.

1149° 1 sec

2. The highest temperature point in the 331 Turbine Section is:

   a. EGT
   b. T4.
   c. T4.1.
   d. T5.

3. When the SRL system computer is on and the engine rpm is above 80%, the EGT limit is:

   a. 650°C for takeoff and 695°C for 96% cruise rpm.
   b. 695°C for takeoff and 650°C for 96% cruise rpm.
   c. 650°C for all flight operation and 770°C in full reverse during landing.
   d. 650°C for all engine operation.

4. If the SRL computer is turned off in flight, the cockpit/EGT instruments:

   a. Will indicate raw EGT.
   b. Will indicate compensated EGT.
   c. Red line limit will be 770°C for 100% engine rpm operation.
   d. Red line limit will be 650°C for 100 and 96% rpm cruise operation.

5. The fuel flow, torquemeters and EGT gages for the left and right engines were closely matched at takeoff. During climb to altitude, the pilot had to gradually retard the left engine power lever to keep the EGT indication within limits. This action resulted in less-than-normal fuel flow and torque. A possible cause for this symptom is:

   a. Incorrect setting number compensating resistor on the left engine.
   b. Oxidized connection in the left engine EGT indicating system causing a secondary thermocouple.
   c. Maximum fuel flow adjustment set too high on the left engine.
   d. Chromel and alumel leads reversed at the left engine EGT instrument.

WORKBOOK EXERCISE 6

6. Raw EGT signals on new engines are compensated at AiResearch to:

   a. Reduce the efficiency of the best engines so that EGT instruments will match.
   b. Increase the indicated EGT to prevent the pilot from damaging the engine when he exceeds the red line limit marked on the gage.
   c. Provide matched EGT indication when the engines are producing matched power.
   d. Increase the efficiency of the least efficient engine to match the rest of the -10 engines.

7. When 24 VDC power was removed from the compensator during a cockpit check of EGT compensator offset, a decrease of 3.3° C EGT was noted. The DSC called for a part number 897205-2 compensator with a number 3 setting. This EGT instrument action indicates that the:

   a. Compensator offset is correct.
   b. Compensator is all right but the EGT indicator has a 3.3° C error.
   c. Compensator is the right part number, but the wrong setting number.
   d. Compensator is the right setting number, but the wrong part number.

8. When the SRL/auto start computer has been turned on, the EGT instrument will indicate:

   a. Compensated EGT up to 80% RPM, then computer conditioned EGT.
   b. Raw EGT.
   c. Computer conditioned EGT from 0 to 100% RPM.
   d. Ambient temperature before the start is initiated.

WHY TORQUE INDICATION?

TPE 331 POWER IS LIMITED BY:

- TURBINE TEMPERATURE LIMIT DETERMINED BY ENGINE MFR AS A FUNCTION OF MATERIAL, SPEED, ENGINE LIFE, ETC
- OUTPUT TORQUE (HP) LIMIT DETERMINED BY AIRCRAFT PERFORMANCE AND STRUCTURAL INTEGRITY

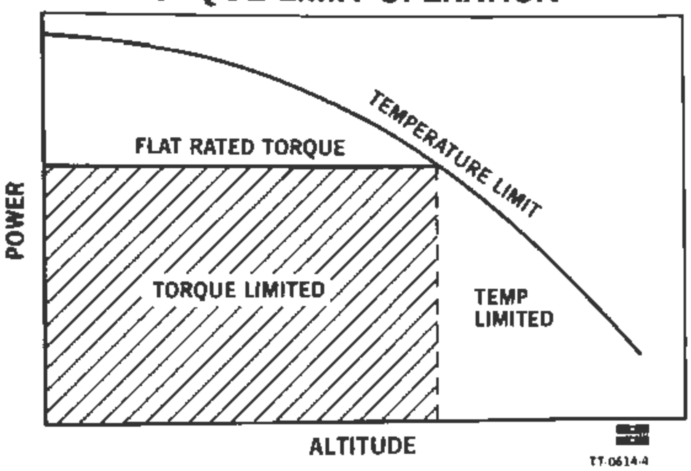
PILOT IS REQUIRED TO MONITOR ENGINE POWER WITHIN THESE LIMITS

TT 614-3

#324

While the maximum temperature the 331 is limited by was determined by the engine manufacturer as a function of the design of the engine, the torque limit is primarily determined by the aircraft manufacturer. He is concerned with aircraft performance and structural integrity in meeting the flight specifications. Exceeding these torque limitations is not only a violation of FAA certification of that aircraft and engine, but may also damage the aircraft or the engine.

TORQUE LIMIT OPERATION

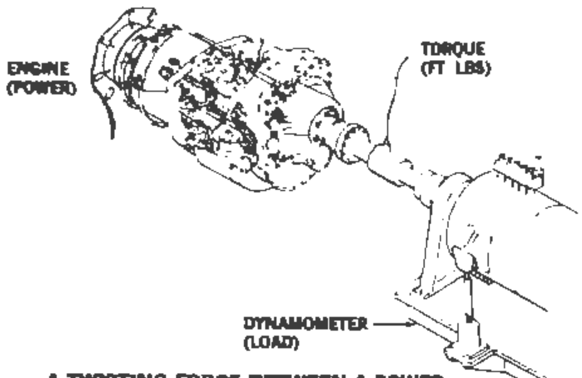


#325

This curve indicates the torque and temperature operation of the 331 Engine on a typical installation. It can be seen that a point will be reached where the temperature limit will take precedence over the torque limit as the aircraft reaches less dense air. That point in pressure altitude or outside air temperature is a matter of the individual torque limit ratings applied by the airframe manufacturer. He may prefer to have the benefits of flat rating that engine to lesser values. For example, if he only needed 665 or 700 horsepower for takeoff, the -10 Engine would be capable of providing that at much higher temperatures and pressure altitudes. This would improve the performance of the aircraft up to some point in altitude where power is lost as a function of being temperature limited.

Regardless of the rating of a particular installation, the pilot must always be aware of the torque limits specified in the Pilot's Operating Handbook, and he will certainly operate the engine on many occasions where the torque limit is the determining factor.

TORQUE DEFINITION



A TWISTING FORCE BETWEEN A POWER PRODUCER AND THE RESISTANCE OF A LOAD

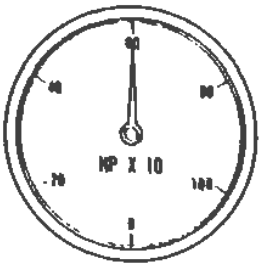
TT-0814-5

#326

This illustration of the 331 Engine attached to a dynamometer in a typical test cell can be used to define torque. The engine in this case is the power producer, creating a twisting moment at the propeller shaft. The propeller shaft is connected to a "Dynamometer," which is a load measuring device in the test cell. "Torque" is the twisting force between the power producer and the resistance of the load. This is equally true in the aircraft when the dynamometer is replaced with a propeller. The propeller is a load absorption device.

Torque is usually measured in foot/pounds (ft./lbs.) or inch/pounds (in./lbs.).

TORQUE INDICATION

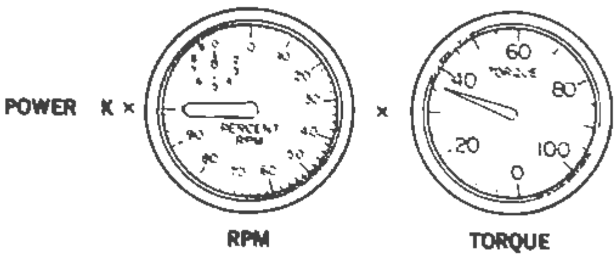


TORQUE (HP) INDICATOR IS ACTUALLY OIL PRESSURE GAGE REFACED TO READ HP-FT LB-%-PSID

#327

Aircraft manufacturers will select different units of measurement for the torquemeter in their cockpit. It may be reading in horsepower, ft./lbs., per cent of torque, or even in psi differential oil pressure. Regardless of the choice of unit of measurement marked on the instrument, all 331 Torquemeter Systems up through the -10 utilize an oil pressure signal provided by the engine torque indication system.

TORQUE × RPM = HORSEPOWER



#328

The actual horsepower at a given torque indication must be related to the effect of rpm. This formula indicates that horsepower is a function of a mathematical constant multiplied by the rpm and then torque indication in ft./lbs.

RPM/TORQUE RELATIONSHIP

$$\text{POWER} = \frac{K}{(.0001904)} \times \text{RPM} \times \text{TORQUE(FT/LBS)}$$

$$900\ \text{HP} = K \times 1591(100\%) \times 2971$$

$$900\ \text{HP} = K \times 1527(96\%) \times 3095$$

TORQUE IS INVERSELY PROPORTIONAL TO RPM

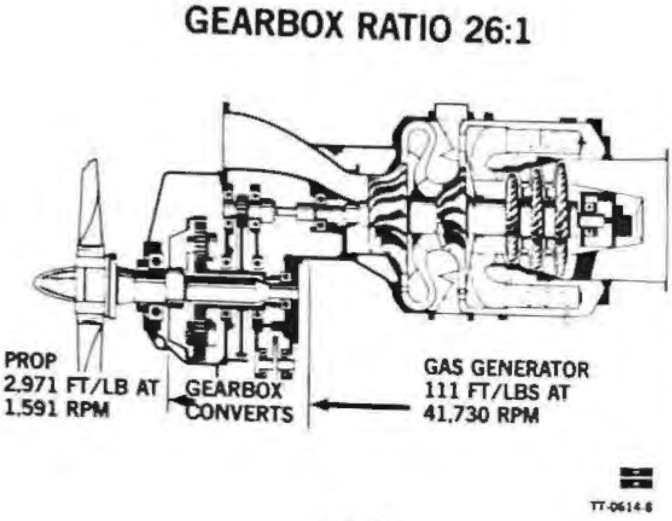
TT-8614-1

#329

PROP MORE EFFICIENT

To illustrate the effect of rpm on the torque being produced at a given horsepower, let's review this sample formula. Assume 900 horsepower is desired for both engine speeds. The K factor is a constant value that does not change. K times 1,591 propeller rpm, times 2,971 ft./lbs., equals 900 horsepower. A red line of 2,971 ft./lbs. under this condition would be representative of 900 horsepower at 100 per cent rpm. If we wished to continue producing 900 horsepower at a reduced rpm--representing minimum cruise of 96 per cent--the propeller rpm would then be 1,527. The formula would work out to 3,095 ft./lbs. to maintain the same 900 horsepower. Thus, torque is inversely proportional to rpm. A second red line at 3,095 would indicate the torque limit at 96 per cent rpm cruise if the airframe manufacturer were to allow the pilot to maintain the same 900 horsepower.

If your aircraft has only one red line on the torquemeter, it would be established on the basis of the engine running at 100 per cent rpm. The Pilot's Operating Manual should be checked for those numbers authorized on your aircraft.

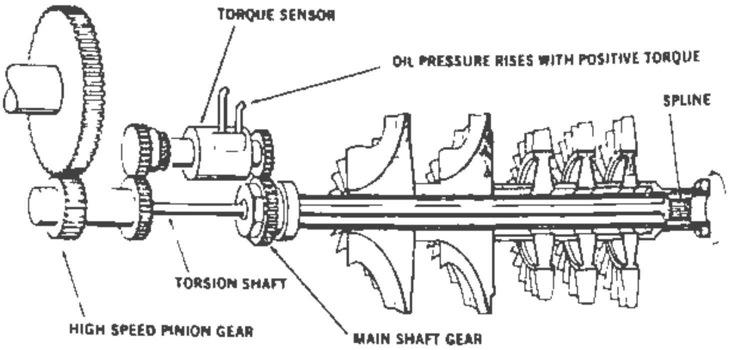


#330

An excellent example of the relationship of rpm and torque can be seen within the 331 Engine itself. As you look at the gas generator portion on the right side of the picture, you know that at 100 per cent rpm, it is turning at 41,730 rpm. The actual torque produced in this sample condition would be only 111 ft./lbs. at that high speed. The gearbox converts this through the gear system to a much slower speed of 1,591 for the propeller. See what has happened to the torque. It's gone from 111 ft./lbs. to 2,971 ft./lbs. The gearbox in this case, does the same job as the transmission in your automobile. High engine speeds can be reduced to low wheel speeds giving you the torque needed to climb the hill.

In the 331 Engine, it can be seen that in order to handle a torque of almost 3,000 ft./lbs., the propeller shaft must be a part with considerable strength. In the gas generator, the connection between the gas generator and the high speed pinion gear is a very small, lightweight shaft. This "Torsion Shaft" is only subjected to 111 ft./lbs. under these conditions. This reinforces the statement that torque is inversely proportional to rpm.

TORQUE SENSOR



TORQUE SENSOR CONVERTS THE TWIST ON THE TORSION SHAFT TO AN OIL PRESSURE SIGNAL

TT 0614-9

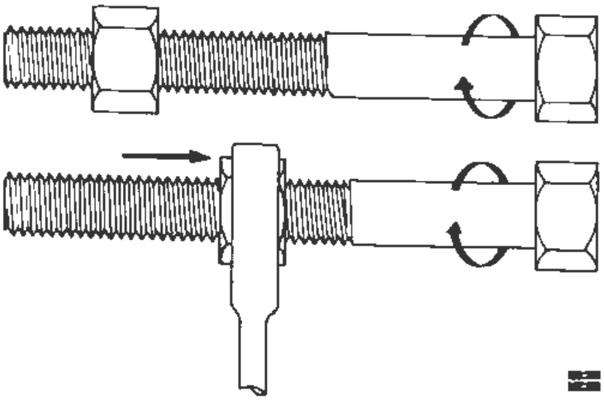
#331

The gas generator shaft transmits its high speed, low torque to the gearbox by means of the torsion shaft. The torsion shaft is splined inside of the main shaft at the rear end. It extends through the center of the main shaft and is splined to the high speed pinion gear. The high speed pinion gear and torsion shaft rotate at the same speed as the gas generator. The torsion shaft is designed to accept the twisting load and spring back to normal when that load is removed.

The heavy gears on the left in this picture represent the load being applied by the propeller and gearbox. As that load is being driven by the gas generator, the torsion shaft would be twisted.

The torque sensor is a mechanical device inside the gearbox that engages with the gears on the main shaft and high speed pinion. This device measures the twist being applied to the torsion shaft and converts it to a corresponding oil pressure signal that is used in the torque indication systems.

JACKSCREW PRINCIPLE

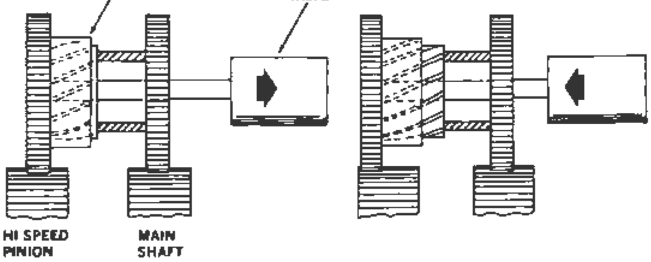


#333

As you examine the inner workings of the torque sensor, you will see that it operates on the basic principle of a jackscrew. The pitch of threads is used to convert rotational forces into a movement back and forth of the nut. The bolt on the top is being turned without any resistance felt on the nut and, obviously, the nut will stay where it is.

The illustration on the bottom shows a wrench being applied to the nut and holding it in a given position. As the bolt is now turned, the thread action would cause the nut to move to the right. Holding the nut as the bolt is turned in the opposite direction would cause the nut to move to the left.

TORQUE SENSOR THEORY



HELICAL GEAR SET CONVERTS ANGULAR DISPLACEMENT OF THE HI SPEED PINION AND MAIN SHAFT GEAR INTO LINEAR MOVEMENT OF A PILOT VALVE

TT-0614-12

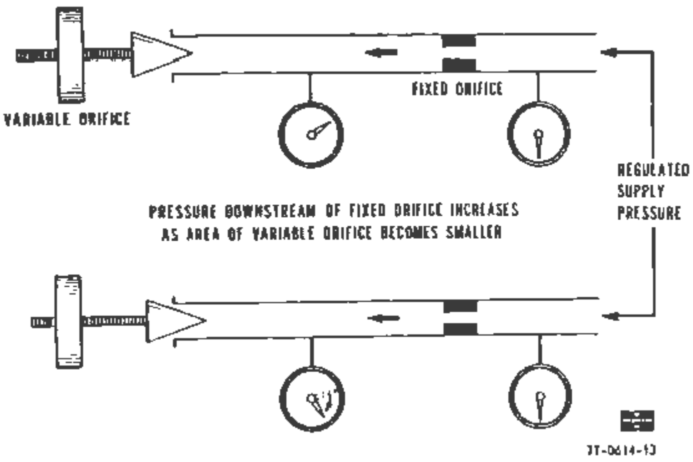
#334

The torque sensor utilizes this jackscrew principle by means of a "Helical Gear Set." This is a male and female gear which has teeth on an angle. This helical gear set converts the angular displacement of the high speed pinion and the main shaft gear into a linear movement of a pilot valve.

The illustration on the left, shows that the female gear is attached to, and driven by, the high speed pinion. The high speed pinion gear represents the gearcase end of the torsion shaft. The male helical gear is driven by a gear attached to the end of the main shaft. This then represents the gas generator end of the torsion shaft. As the engine is being operated and power is increased, the twisting of the torsion shaft will result in an angular displacement of the high speed pinion and main shaft gears.

Even though they are turning at the same speed, the twist of the shaft will allow one gear to be slightly different in its relationship to the other gear. This angular displacement is converted by the helical gear set into a linear motion of the pilot valve. The illustration on the left indicates an increase in torque causing the pilot valve to move to the right. The right side picture indicates a lesser torque being applied causing the pilot valve to move left. The pilot valve can now be the prime control point in a torque indicating system.

BASIC DUAL ORIFICE CONTROL



#335

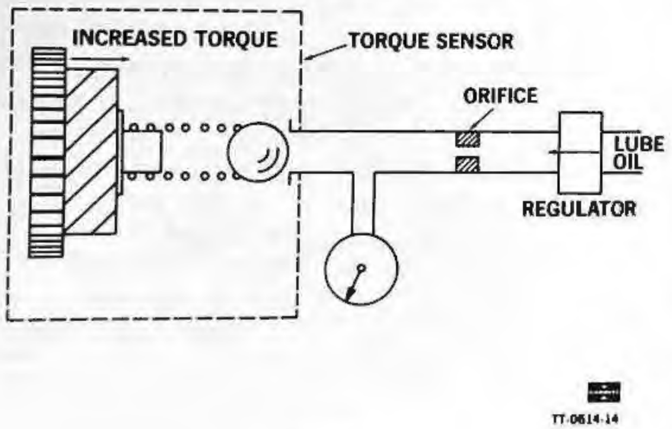
The torque indication system in the 331 Engine utilizes the "Dual Orifice Control System" principle. The top illustration shows a regulated supply of oil pressure entering the system from the right. The oil would flow through the fixed orifice into the cavity on the left. The flow that escapes through the variable orifice must be replaced. The fixed orifice acts much like a resistor in an electrical system where flow of current through the resistor causes a voltage drop. In a fluidic system, the flow of the fluid through the orifice results in a pressure drop. So the gage reading on the left would be lower than the supply pressure as a function of the pressure drop across the fixed orifice.

The illustration on the bottom shows the same system with the same regulated pressure coming on the right side, but now the variable orifice has been moved closer to the seat.

Less flow through the fixed orifice would cause less pressure drop. The gage downstream of the orifice would move to a higher value. As we maintain a constant regulated supply and a fixed orifice, the pressure will increase or decrease downstream of the orifice as a function of the variable orifice closing or opening. The pilot valve in the torque sensor that we just described, serves this purpose in the system of the variable orifice.

In principle then, the instrument measuring the pressure between the fixed and variable orifices could, in effect, measure and indicate the torque being sensed by the torque sensor.

BASIC FLUID SYSTEM

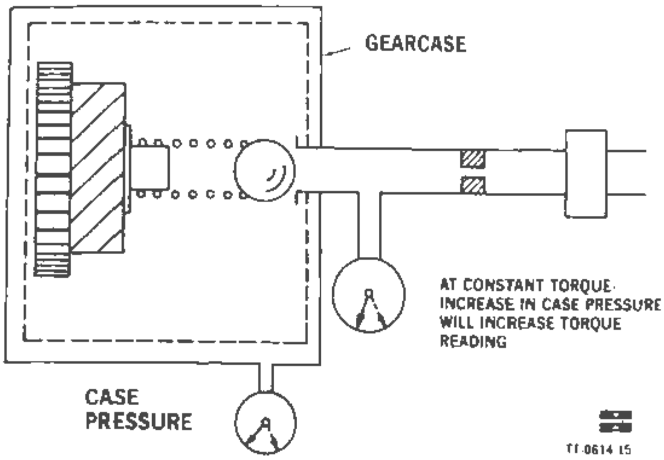


#336

Let's now put together the torque sensing system utilizing the principles of the dual orifice system and the torque sensor as previously described. In this system, we can see that lubrication oil system pressure coming in at the right side is the source of the working fluid for the torque indicating system. It is first supplied to a regulator that reduces the lubrication oil pressures to a constant regulated value. (Note: Engines produced after July 1980, or prior engines incorporating SB72-0257, will not have this regulator installed. It will be replaced by an orifice.) Downstream of the fixed orifice, we have attached an instrument to measure the pressure at that point. Remember that the cam action of the helical gear set would move towards the right on an increased torque condition; this in turn, would move the spring loaded ball toward the seat causing an increase in pressure between the fixed orifice and variable orifice.

That oil that flows through the ball seat arrangement would drain into the case of the engine.

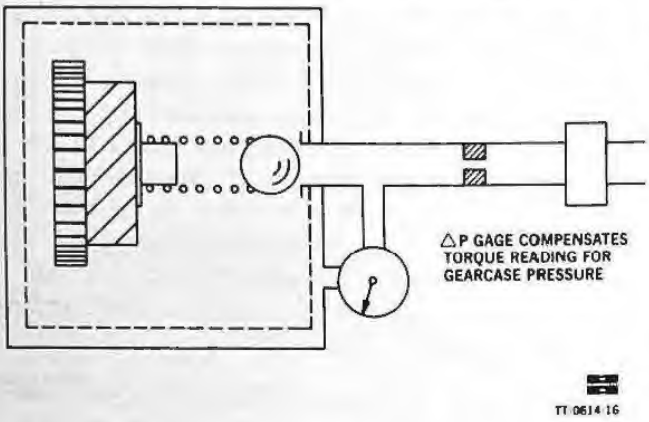
GEARCASE PRESSURE EFFECT



#337

The downstream side of the metering valve is subjected to whatever pressures are felt in the gearbox. The pressures in the gearbox on the 331 Engine operate at a negative level due to the action of the oil system scavenge pumps that pump oil and air out of the case. This illustration points out that as the torque sensor pilot valve is mechanically positioned, any change in case pressure would change the measured pressure due to the fact that the oil flow would vary as the differential varied across the metering valve. This means we must take case pressure into account in the torque indicating system. If we were to instrument the system as shown, having a gage indicating the torque oil pressure signal and separate vacuum gage measuring the case negative pressure, the actual torque indication would be a combination of the two. Rather than making two separate gage systems, they can be incorporated, as seen on the next picture.

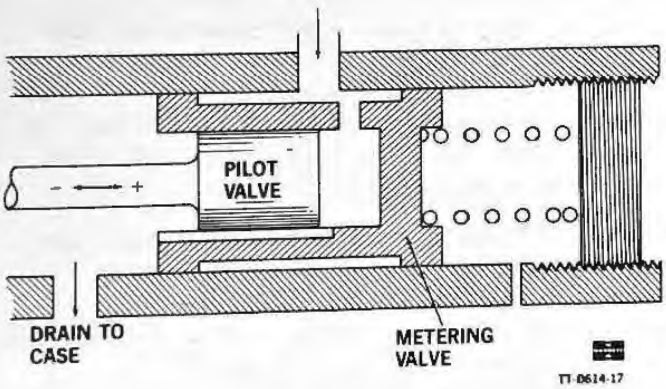
DIFFERENTIAL PRESSURE GAGE



#338

A differential pressure gage can give one indication, taking into account both case pressure and torque signal. Differential pressure is often referred to by the symbol shown as "Delta P." It is important for the maintenance mechanic to recognize this since all values given in the torque indication systems will be given in "PSID," or "Pounds Per Square Inch Differential." This will be important when calibrating the system.

TORQUE SENSOR METERING VALVE

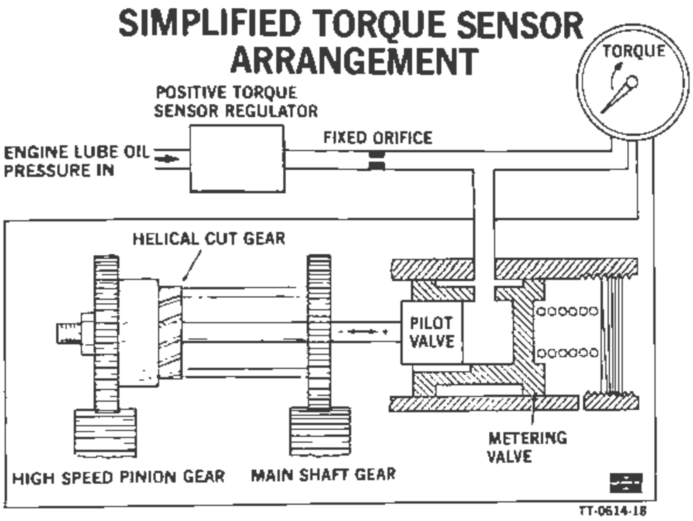


#339

We can now look at the actual mechanical construction of the torque sensor.

The pilot valve is operated by the helical gear set of the torque sensor. It operates in a sliding metering valve that is spring loaded. The oil pressure downstream of the fixed orifice enters this part of the assembly from the top center. As oil pressure builds up in the cavity at the end of the pilot valve, it also bears against the metering valve. Remember, the pilot valve right now is mechanically fixed in one position by the action of the helical gear set measuring the twist of the torsion shaft. As the oil pressure against the metering valve face tends to exceed the spring value, it will move the metering valve to the right, uncovering the port shown at the bottom edge just enough to maintain a balance of forces between the spring value and the oil pressure.

If at this point the pilot valve were moved to the right by the torque sensor, it would close the drain port and prevent the oil from escaping into the case. The oil pressure in the metering valve would increase in value until it was capable of moving the metering valve far enough to the right against the increased spring tension to the point required to balance the forces of the metering valve against the spring.



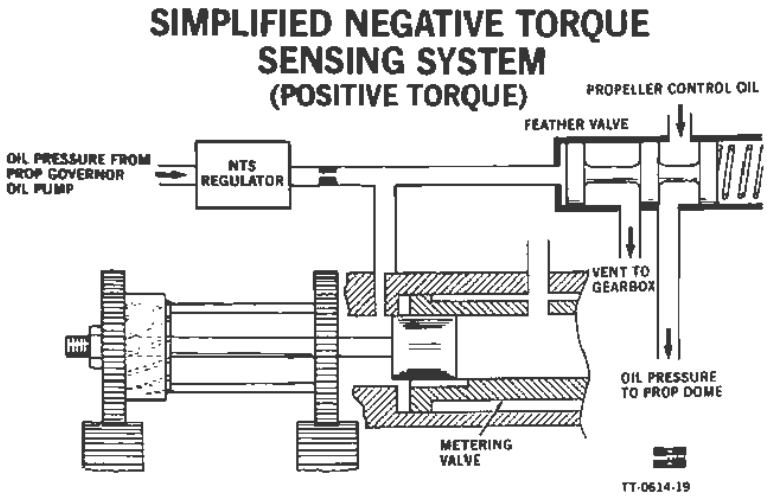
#340

This illustration combines all the elements previously discussed. Engine lube pressure generally operates around 100 psi. The regulator reduces this to approximately 80 psi to maintain a constant regulated supply to the dual orifice indicating system. That regulated supply flows through the fixed orifice down to the torque sensor. The pressure maintained in the system downstream of the fixed orifice is a function of the position of the pilot and metering valves.

The differential pressure gage is used as a torque indicator and would be sensing the torque pressure on one side, case pressure on the other side. This automatically compensates for the change in case pressures to give the indicator an accurate reference under these varying conditions. The system shown here could provide an adequate indication of the torque being produced by the engine.

During the propeller discussion, you learned that the torque sensor also entered into an operation involving negative torque.

Negative torque occurs when the power has been lost and the engine is being driven by the propeller. A negative torque signal causes action in an NTS system. Let's examine that part of the torque sensor system.

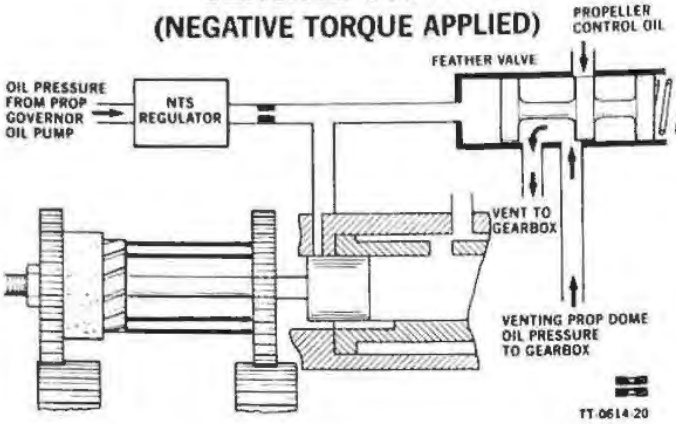


#341

In order to understand the torque sensor's contribution to the negative torque sensing system, let's first examine the NTS system under normal flight conditions where positive torque is being maintained. The positive torque indication system previously described has been eliminated from this illustration for simplicity.

The components of the negative torque sensing system are indicated here. Oil pressure from the propeller governor oil pump is the source of working fluid for the NTS system. The NTS regulator will reduce and regulate the oil to 100 psi to provide a stable pressure to the dual orifice system. That regulated pressure flowing through a fixed orifice is available to the end of the feather valve and to an open drain port in the torque sensor. The feather valve is in it's normal position allowing propeller control oil to go through the pitch control to the propeller. The metering valve in the torque sensor is in a normal positive torque position. Under these conditions, the oil pressure downstream of the fixed orifice in the NTS system is allowed to drain unrestricted into the gearcase and consequently, there is no pressure buildup on the end of the feather valve.

SIMPLIFIED NEGATIVE TORQUE SENSING SYSTEM
(NEGATIVE TORQUE APPLIED)



#342

Remember that the helical gear set in the torque sensor causes the pilot valve to move to the right under positive torque. Let's assume in this case that the engine has flamed out and is now being driven by a windmilling propeller. This is negative torque. The twist in the torsion shaft would cause the helical gearset to move the pilot valve to the left. The pilot valve now closes the drain port of the NTS system and oil is allowed to build up rapidly on the end of the feather valve. When that pressure reaches a value slightly above 30 psi, it is sufficient to stroke the internal piston assembly of the feather valve to the right. This blocks off the propeller control oil and vents the oil that is in the propeller back through the feathering valve into the gearbox. Obviously, the propeller would start to move immediately toward the feather position because of the loss of control oil.

As the propeller moves toward the full feathered position, torque felt by the torsion shaft and torque sensor would become less negative. The pilot valve moves toward the right again, uncovering the port allowing the NTS pressure to escape into the case. Reducing that pressure allows the feather valve to reseat, returning propeller control oil to the propeller and driving it back towards a lower blade angle. When this occurs, the torque sensor will sense an increase in negative torque because of windmilling action. This again reflects in a movement of the pilot valve to the left and an increase in NTS pressures to operate the feather valve.

This results in the cycling referred to as "NTSing." The propeller will continue to cycle at a reduced drag level giving the pilot complete control over the aircraft.

You can now see that the torque sensor provides the variable orifice operation in two separate fluid systems. When the pilot valve moves to the right, it is controlling the torque indication system, when the pilot valve moves to the left, it is operating the NTS system.

TORQUE SENSOR OUTPUT CHARACTERISTICS

RAW OUTPUT SIGNAL FROM EACH ENGINE'S TORQUE SENSOR IS AS INDIVIDUAL AS HUMAN FINGERPRINTS DUE TO:

- MANUFACTURING TOLERANCE OF ORIFICES, BORES, VALVES & ETC
- ACCEPTABLE VARIANCE IN SYSTEM LEAKAGE RATES
- OPERATING TEMPERATURE OF WORKING FLUID
- TYPE OF FLUID IE. MIL-L 7808 OR MIL- L 23699
- DIFFERENCES IN GEARBOX NEGATIVE CASE PRESSURE
- TORQUE SENSOR CALIBRATION TOLERANCE

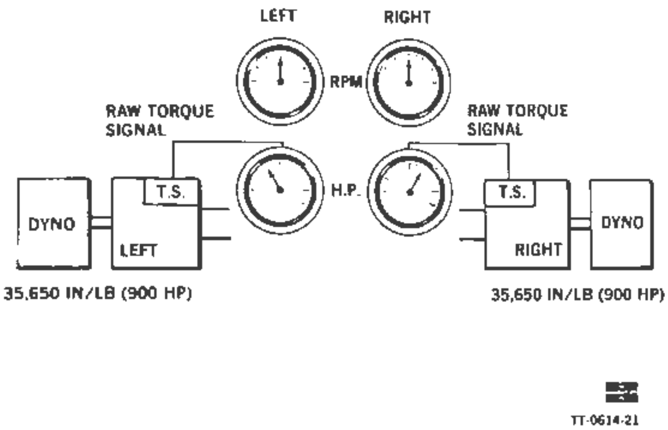
TT-0614-35

#343

The torque signal oil pressure discussed up to this point is called the "Raw Torque Signal," since it is the pressure received directly from the torque sensor. Due to variations between engines, the raw torque signal of each engine is only true for that particular engine. For example, any mechanical part has acceptable manufacturing tolerances. Any minor differences in the size of orifices or metering valves would have an effect on the pressure at any given torque setting. Obviously, the viscosity of the oil is affected by temperature and oil type and the flow through a given sized orifice would be affected by this viscosity. Also differences in gearcase negative pressures can be a result of different efficiencies in the lubrication system scavenge pumps. Finally, the calibration procedure for a torque sensor at the time of installation is also a mechanical procedure subject to acceptable tolerances.

When considering all of these variables, it is understandable that no two torque sensors would give identical raw signal pressure readings even though the compared engines may be operating at the same level of torque. Let's examine this in the test cell operation.

NEED FOR COMPENSATION

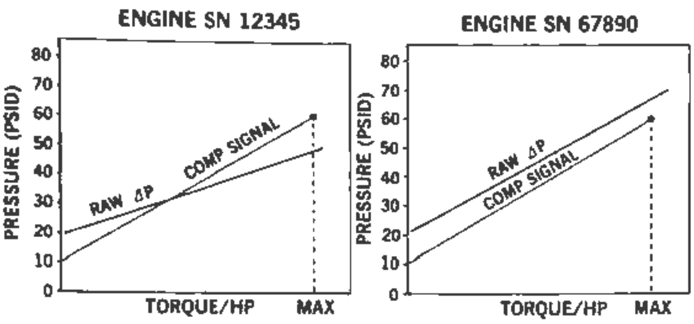


#344

Let's make the assumption that the left and right engines have been removed from an aircraft and put into a test cell environment. Each engine is mounted to a dynamometer. The dynamometer, as you already know, is a precise torque measuring device, in fact, in the Garrett test cell, torque is measured in inch/pounds to provide greater accuracy. Assume that the left engine mounted to the dynamometer in one test cell was run at a condition of 100 per cent rpm and provided precisely 35,650 inch/pounds of torque. This is 900 horsepower. The raw torque signal from this left engine is connected directly to an indicator and, let us assume, for sake of illustration, that the indicator pointed precisely at 900 horsepower. This would represent an accurate torquemeter system. Now let's look at the right engine. The right engine is installed in a cell, connected to a dynamometer, and is run to provide precisely the same 35,650 inch/pounds of torque. But the raw torque signal coming from the torque sensor to the instrument indicates something different. It is obvious that this condition could not be conducive to good pilot monitoring. The Pilot's Operating Handbook gives him one number and says, "This is your maximum torque, do not exceed."

It does not identify that torque to a specific engine serial number, it says ALL engines. This situation points out the need for some externally adjustable compensation to these raw torque signals. It is necessary because we must provide an accurate indication of the horsepower actually produced by both engines.

ENGINE DSC (DATA SHEET CUSTOMER)



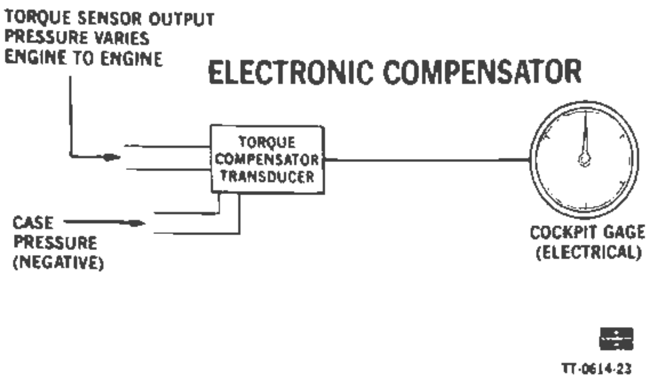
TT 0614-22

#345

When each engine is connected to a dynamometer and run in a test cell, it runs to an exact value of horsepower. The technician in the test cell will then record what raw torque pressure signal is obtained from the torque sensor on that engine. This information is included on the engine DSC, or data sheet, shipped with the engine.

These sample curves indicate two different serial number engines and comparative raw torque signals that are quite different. The compensated line on these curves indicates the exact duplication of a torque signal that must be provided to the torque indicator at each level of power being produced. The signals on both of these engines need to be conpensated so that they give the indicating system of the aircraft precise values, as indicated by the compensated line.

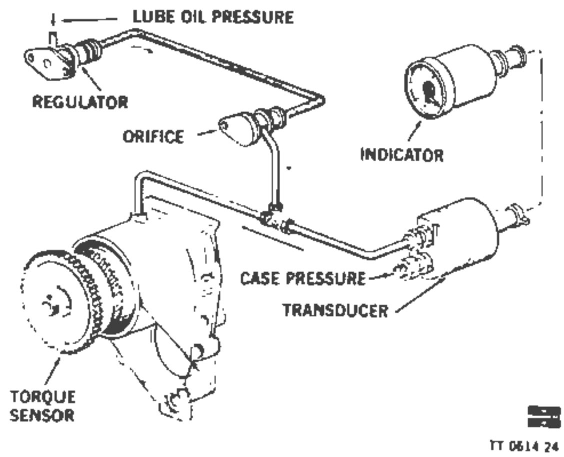
TYPICAL TORQUE INDICATING SYSTEM



#346

Most modern aircraft utilize electrically operated instruments. This provides the capability of utilizing a transducer in a dual function. A simple transducer normally converts a fluid signal to an electrical signal. In this case, the transducer is also adjustable and becomes an electronic compensator. The signals of torque sensor output and case negative pressures are applied to one side of the transducer and the transducer is calibrated to compensate this information to the electrically operated cockpit indicator. Some TPE331 Models utilize a "Hydraulic Compensator" that provides the same compensating function. The calibration procedure of both types of compensator will be covered in detail in the practical activities portion of this factory training program.

TORQUE INDICATING SYSTEM

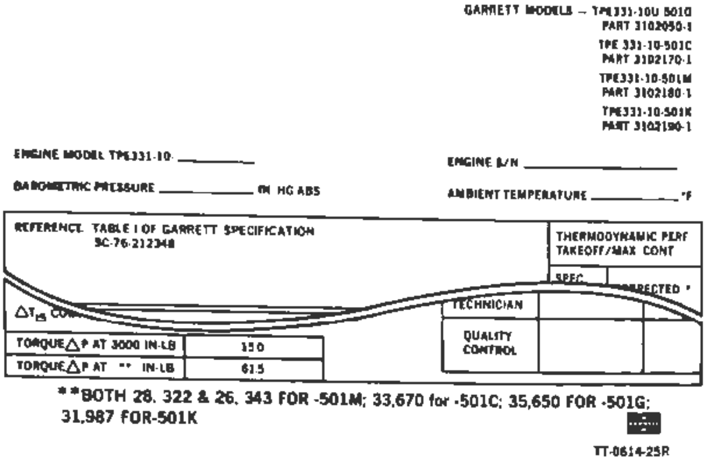


#347

This illustration indicates the connection of the various components in a typical torque indicating system that utilizes an electrical compensator.

In the upper left, lube oil pressure is regulated and flows to an orifice assembly. These two devices are mounted externally on the left side of the gearcase. The torque sensor is mounted inside of the gearcase. The controlled raw torque signal is now sent external of the engine to the transducer. The transducer is also connected to case pressure. The transducer is calibrated to compensate those signals to an accurate electrical signal to the indicator in the cockpit.

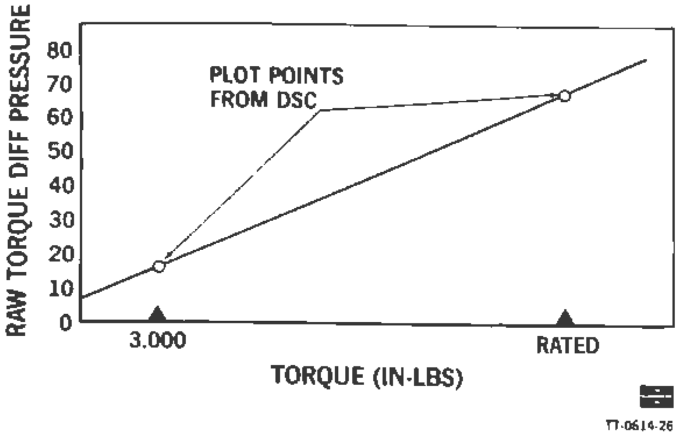
DSC RAW TORQUE DATA



#348

The portion of the engine data sheet that is relative to the torque indication system is shown here. Notice in the upper right hand corner that this data sheet is applicable to various installations of the -10. A data sheet will be made out for each engine shipped. At the bottom of the data sheet, you will note various numbers in in./lbs. of the torque representing the rated horsepower of the various installations. In the lower left hand corner of the data sheet, you will see two numbers. The torque differential pressure at 3,000 in./lbs. is 15 psid, in this sample. The torque differential at the rated power setting is 61 1/2 psid. These raw torque values are given at a low level of power as well as the rated power condition, representing a straight line function between low to high power. The transducer can be calibrated to give a compensated reading that will be accurate at all levels of power. Remember that these are sample numbers used only for purposes of this illustration. Raw torque valves will be different for each engine by serial number.

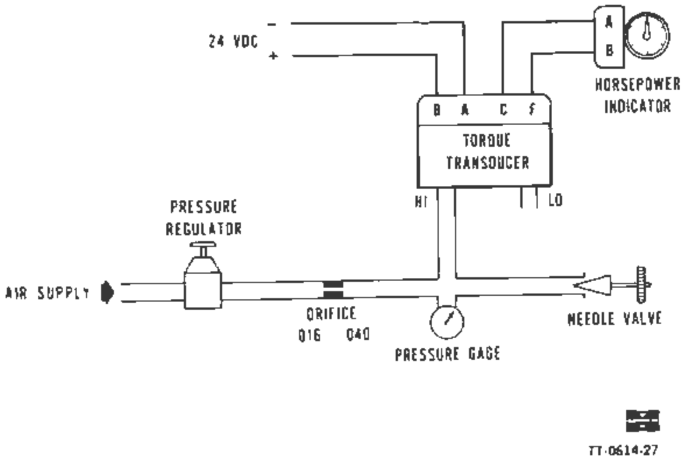
RAW TORQUE SIGNAL



#349

This curve illustrates the straight line function previously described. The two power points taken from the data sheet have been plotted. A straight line drawn between those two points would indicate the raw torque signal at any level of torque between the minimum to the rated condition.

TRANSDUCER CALIBRATION

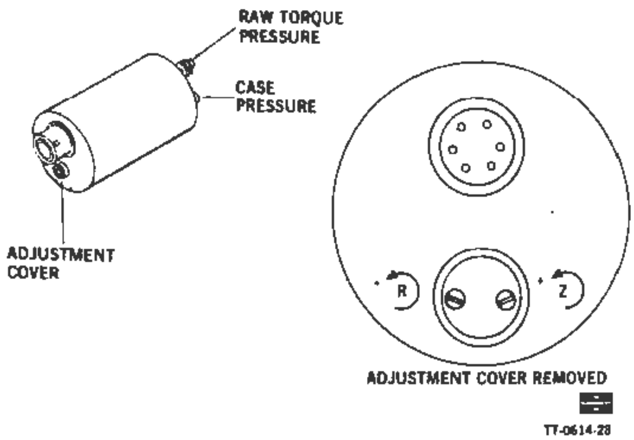


#350

This is a simple schematic of a test rig that can be used to calibrate the electrical torque transducer. It can be used when the transducer is installed in the nacelle, or it can be done in a shop area as a bench check. The requirement in this case would be for a regulated air supply, simulating the raw torque signal.

This particular test rig uses a combination of a fixed orifice with a very fine needle valve so that accurate regulated pressure can be controlled. When the appropriate pressure is applied, the transducer can be calibrated to provide an accurate signal to the horsepower indicator.

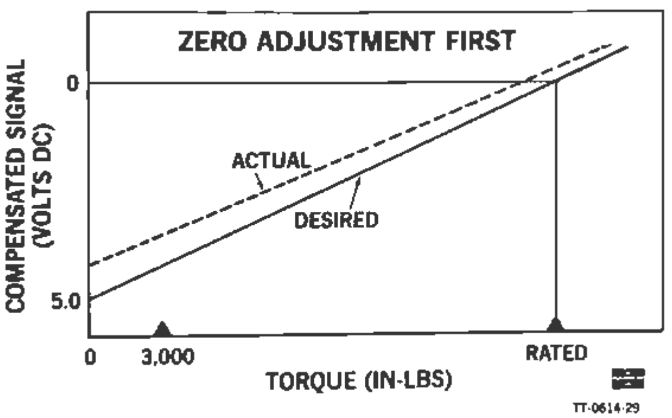
COMPENSATING TRANSDUCER



#351

This picture shows the transducer adjustments. The view on the left identifies the raw torque pressure and case pressure ports. On the other end of the transducer, below the electrical connector, is the adjustment cover screw. When the cover screw is removed, you will see two small screws inside of that port. The range screw on the left is identified to turn counterclockwise to increase. The zero screw on the right also turns counterclockwise to increase.

ZERO ADJUSTMENT



#352

On the left side of this curve, you can see the output of the transducer as a compensated signal in volts dc. This can be used on a bench calibration test utilizing a digital voltmeter and referring to the particular volts called out in the maintenance manual. It also represents the reading that might be obtained on the aircraft instrument itself.

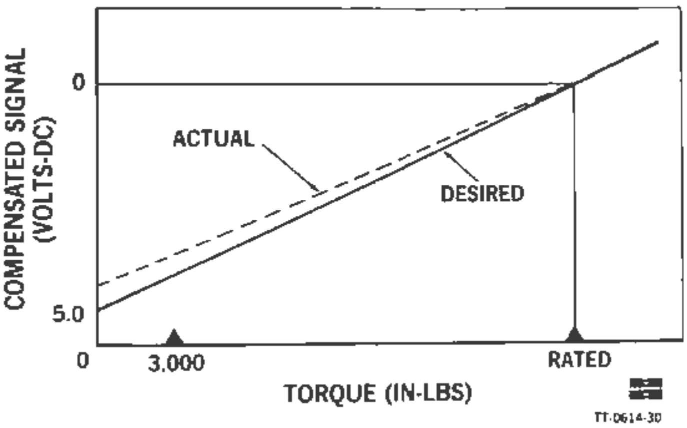
The high and low points of torque, according to the data sheet, are identified at the bottom. With the system hooked up to the calibration rig that we described before, the appropriate pressures for 3,000 in./lbs., or for rated torque, could be applied to the system, and the output signal should agree with the desired levels of power either read on the torquemeter or the bench voltmeter. The bottom line represents the power level signal that should be read under those conditions of torque.

The top line is a sample of what we might actually find if we were to start out with the transducer that is not calibrated. It is obvious that the actual line does not match the desired line. The actual line is too high and it's at the wrong angle, or slope.

The first adjustment will be the "Zero Adjustment." We need to get the zero volt signal at rated power. If we go to the zero adjustment screw on the transducer and turn it in the correct direction, we should see the following results.

RANGE ADJUSTMENT

RANGE ADJUSTMENT AFTER ZERO ADJUSTED

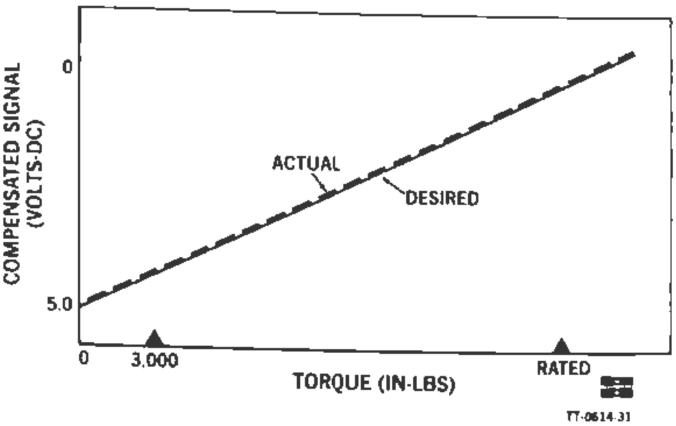


#353

This curve reveals that the desired action of zero adjusting has taken place. We are now correctly aligned to the rated power point with a zero volt signal. The actual signal line has been dropped, but the actual pressure line has not yet been put on top of the desired line at the lower power levels.

When the zero adjustment has been made to attain zero volts at rated power, the range adjustment is then used to correct the slope condition. Turning the range adjustment screw in the correct direction will change the slope of the actual line without affecting the zero point.

FINAL ADJUSTMENT CHECK

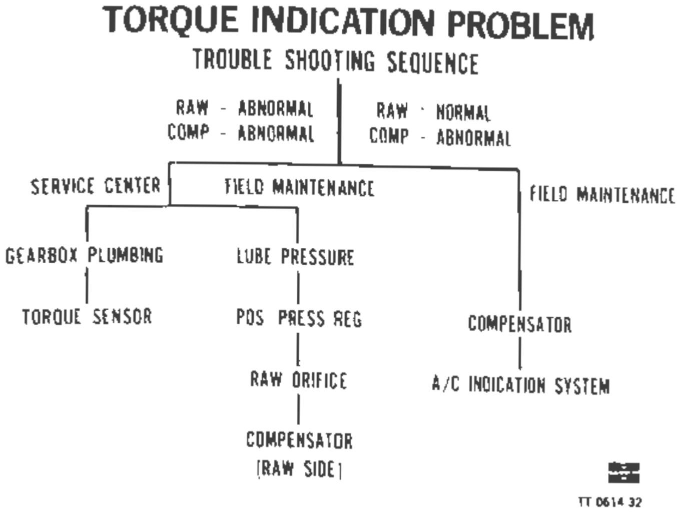


#354

The effect of range adjustment is shown on this curve. We have now dropped the lower end of the actual curve to match the desired point and we have not changed the zero voltage point at rated power. The electronic transducer is now calibrated to accurately reflect the actual power being produced on the aircraft instrument.

It is a relatively simple procedure to calibrate the transducer if you have a valid data sheet indicating raw torque signal numbers. This is a point to be considered because if maintenance action which includes separating the torque sensor has been accomplished, the raw signal will be recalibrated as the torque sensor is installed. It is the responsibility of the service center that does such work to revise the data sheet or engine log to reflect the raw signal that has been calibrated as the torque sensor has been reassembled.

If you're going to attempt to adjust the torque compensator, check the engine log book and make sure that a raw signal has been provided by the service center if the gearcase has been opened. If such is not the case, the maintenance manual describes the other alternative available to you in calibrating the torque transducer without a valid data sheet. That procedure involves the use of a portable dynamometer known as the "Lebow." This kind of test equipment is available at the major repair service stations. Remember the line maintenance mechanic needs a valid data sheet on each engine in order to properly calibrate the torque indication system.



#355

This chart can assist you in troubleshooting a possible torque indication problem. The major point made on the top of the chart is the ability of the mechanic to verify whether the raw torque signal is normal or abnormal. For example, looking on the right side of the chart, we have determined that the raw torque signal is normal, and only the compensated signal is abnormal. If this is the case, the solution is relatively easy and can be done at field level. The problem must lie in the compensator, or in the aircraft indicating system.

On the other side of the chart, we see a condition in which the raw torque pressure is determined to be abnormal and the compensated signal would also be abnormal. There is still a possibility that field level maintenance can solve the problem because we see such things as inadequate lubrication oil pressure, improperly set positive pressure regulator, restriction in the raw orifice in the torque indicating system or a problem on the fluid side of the compensator itself. If this is true, the raw torque signal can be corrected by the appropriate action in these areas. If those checked out well, then the problem would have to be internal. In order to check the internal plumbing and torque sensor, you need the service center tooling necessary to disassemble, and reassemble the gearbox and to recalibrate the torque sensor.

The obvious question is, "How do I know whether the raw signal is normal or not?"

It is a good idea to make some records in your engine log book relative to the raw torque signal attained with the propeller in full reverse when the engine is in good condition. Since this is a repeatable load that can be done anytime, it's easy to measure the raw torque signal and see whether it's reasonably close to what it was in full reverse when the engine was in good condition.

WORKBOOK EXERCISE 7

SUBJECT:
SECTION 9 - TORQUE INDICATION

1. Which of the following would cause a pressure increase between the orifices in a dual orifice control system?

   a. Reducing the size of the variable orifice.
   b. A fixed orifice of reduced size.
   c. A decrease in regulated pressure.
   d. Both "a" and "b" are correct.

2. What is the horsepower produced with the TPE331-10 Engine operating at 98% rpm and a torquemeter reading of 2970 ft./lbs.?

   a. 900 HP.
   b. 882 HP.
   c. 864 HP.
   d. 846 HP.

3. Which statement is true concerning the torque indication system?

   a. The raw torque ΔP value is the same for all engines.
   b. To calibrate the torque indication system, you adjust the raw torque ΔP to match engines.
   c. The transducer receives a raw ΔP hydraulic signal and is adjusted to produce a compensated electrical signal.

4. How much horsepower is being produced by a TPE331-10 Engine during a static full reverse with an engine speed of 96% and a torquemeter reading of 1430 ft./lbs.?

   a. 864 HP.
   b. 481 HP.
   c. 432 HP.
   d. 416 HP.

Questions 5 through 10 state possible problems within the torque indication system. Select from the following list, the answer that best describes the effect on the torquemeter reading.

   a. Low indicator reading.
   b. High indicator reading.
   c. Normal indication.
   d. Maximum (redline) indication .

5. A restricted raw orifice.

   a. c.
   b. d.

WORKBOOK EXERCISE 7

6. Loss of 24 VDC power to the transducer while the engine is running.

a. c.
b. d.

7. Low supply pressure from the lubrication system.

a. c.
b. d.

8. A leaking "O" ring on the raw orifice assembly creating a parallel flow path, and having the effect of a larger orifice.

a. c.
b. d.

9. The filter upstream of the orifice assembly is restricted by excessive contamination.

a. c.
b. d.

10. Loss of the electrical signal from the transducer to the indicator during engine operation.

a. c.
b. d.

11. After installing a new engine, the mechanic recorded in the engine log the full reverse torque pressure of 27.5 PSID. While troubleshooting, you obtained the following reading in full reverse. Case negative: -7 in. HG., Raw: 24 PSIG. How does this compare to the original value?

a. Raw ΔP is the same.
b. Raw ΔP is lower than normal.
c. Raw ΔP is higher than normal.

WORKBOOK EXERCISE 7

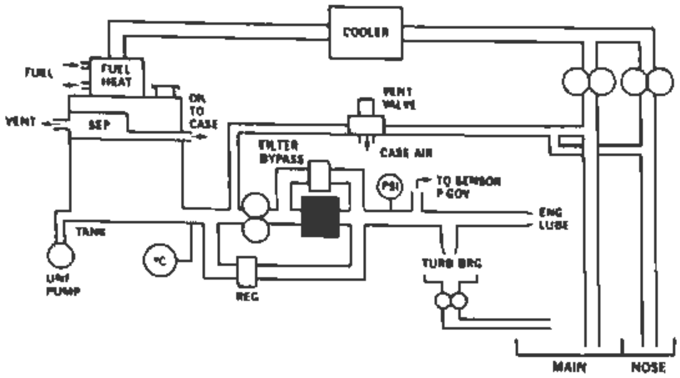
12. To check and adjust a torque transducer, you obtain from the engine permanent records 21.5 PSID and 62.5 PSID, representing the low and high torque pressure values respectively. Knowing that the engine in question operates at a case negative of -5 in. HG, what pressure values would you apply to transducer high pressure port to bench calibrate the system?

a. 17.5 psig and 57.5 psig.
b. 19.0 psig and 60.0 psig.
c. 21.5 psig and 62.5 psig.
d. 24.0 psig and 65.0 psig.

SECTION TEN:

LUBRICATION SYSTEM

SIMPLIFIED LUBE SYSTEM



TT-0615-3 R

#359

The lubrication system in the 331 Engine does basically the same things as lubrication systems have done in all engines. In this simplified schematic, the complete flow cycle can be reviewed. Oil from the tank can be taken out through the unfeathering pump connection as shown in the lower left. The normal exit is to the pressure pump. Temperature is measured at this point. The output of the pump is regulated by a pressure regulator in parallel with the pump. A pressure signal is sent to the panel instrument. The filter element also has a bypass in parallel in the event that the filter is restricted. Clean and pressurized oil is then available to the engine.

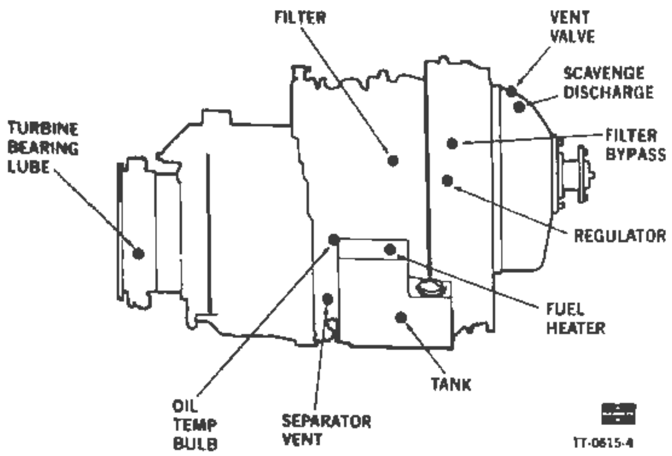
You will note that oil pressure is available to the torque sensor indicating system and to the prop governor. The other jets represent the many engine lubricating points including the turbine bearing. The only external oil plumbing on the engine is a line carrying oil back to the turbine section. All other ports and passages are internal.

The oil that's in the engine then settles into sumps, one located back in the turbine section and two in the main case. Oil from the turbine sump is picked up by a small pump and sent back through the torsion shaft and discharged into a main sump in the gearbox. In the upper right hand corner is a dual scavenge pump. Each of these pumps takes oil from its respective sump and sends it to the aircraft mounted oil cooler. Oil from the cooler is sent back to the tank through a fuel heater.

The warm oil provides heat energy to keep the fuel warm enough to prevent icing of the filter in the fuel system. The oil and air mixture in the tank is directed to the "Separator." This is a device that takes the air from the oil and vents it overboard. The solid oil is returned to the gearcase. This lubrication system is very typical of those found on most engines.

The one unique feature of this system is represented by the vent valve located in the center of the drawing. The purpose of the vent valve is to reduce the load of the oil pumps during the initial starting phases so that the additional power available can be used for cranking the engine. Remember, this is a fixed shaft engine and during any rotation of the engine, all parts will turn together. The vent valve is energized open from the initiation of the start up to the 60 per cent speed point. It allows case air to enter into the inlet of the high pressure pump and the two large scavenge pumps. This allows these pumps to pump oil and air, reducing the total drag against the starter. When the engine accelerates above 60 per cent speed, the speed switch will close the vent valve.

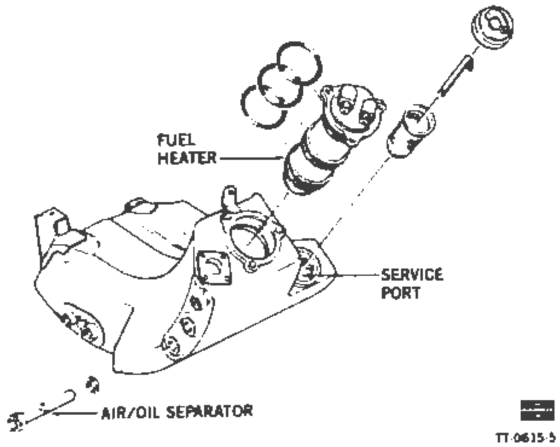
LUBE SYSTEM COMPONENTS



#360

This artwork identifies the general location of the major components in the lubrication system. The vent valve is on the nose case of the engine. Right next to it is the discharge from the two scavenge pumps. The filter bypass is located on the right side of the gearbox, and right below it is the regulator. The fuel heater is usually mounted inside of the oil tank, as is the air/oil separator. The oil temperature bulb is located right above the tank. The turbine bearing lubrication line is at the aft end of the engine. The filter element is right below the fuel control. These components will be investigated as necessary in the next few pictures.

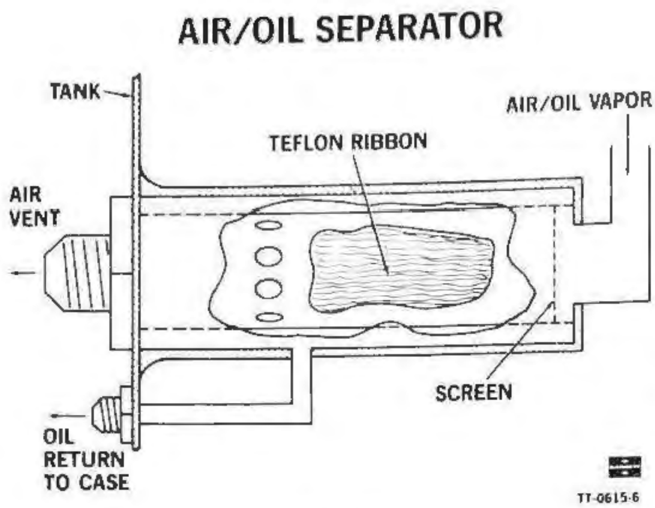
OIL TANK



#361

This is a view of the engine oil tank as mounted on a typical inlet down TPE331. On the 331 Engines where the inlet is down, the oil tank is provided by Garrett and is mounted as part of the engine. On engines using the inlet up configuration, the oil tank is provided by the aircraft manufacturer and is generally mounted on the firewall.

The service port includes a screen, dipstick, and a cap. The "Air/Oil Separator" is a tubular device screwed into a port in the oil tank. The "Fuel Heater" is a cylindrical heat exchanger mounted into the oil tank as shown. Other ports on the tank--including a connection for the unfeathering pump and a drain port--are shown in the lower left.



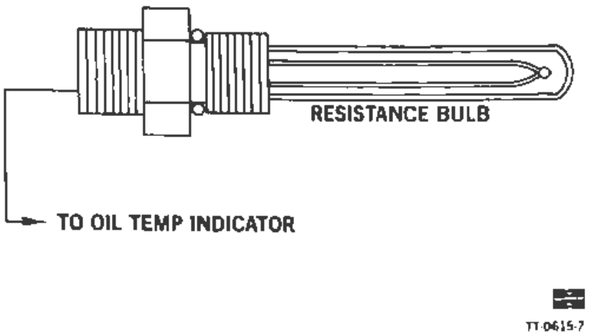
#362

The air/oil separator--shown here--is threaded into a port in the oil tank. It is obvious that the scavenge pumps will pump a mixture of oil and air from the gearbox sumps. The air/oil mixture in the expansion space at the top of the tank enters the air/oil separator in the upper right hand part of this picture. That mixture enters the separator through the screen, shown in the right hand side of the separator, and is then available to pass through the portion of the separator that is packed with teflon ribbon. These ribbons of teflon material have an affinity for oil. Oil will adhere to the teflon. The very tiny droplets of oil stick to the teflon while the air continues to pass to the left and is vented overboard through the air vent connection. As the small drops of oil vapor collect, they join together and become large enough to have weight. When they get large enough, they settle to the bottom of the tubular structure that contains the separator. The oil in this area is returned to the gearcase through external plumbing by the action of differential pressure. The air pressure in the oil tank is slightly positive, and the pressure in the gearcase is negative.

The only maintenance action necessary will be the periodic cleaning of the air/oil separator. The manual describes a procedure for removing the separator and cleaning it. Evidence that the air/oil separator needs cleaning is often provided by excessive oil vapor being discharged from the air vent.

OIL TEMPERATURE BULB

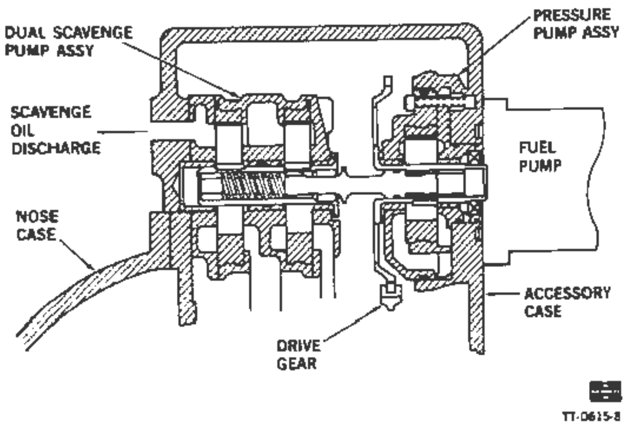
TYPICAL RESISTANCE
AT ROOM TEMP = 100 ± 50 OHMS



#363

The "Oil Temperature Sensor" is located in the inlet line from the tank to the pump inlet connection on the back of the accessory case. It is a standard system in which the resistance of the bulb is varied by temperature. Typical resistance at room temperature is 100 plus or minus 50 ohms. These units rarely cause any problem.

PUMP ASSEMBLY

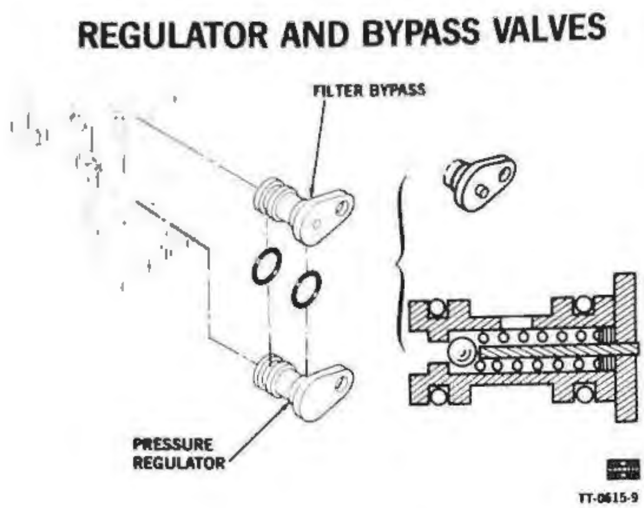


#364

The pressure and dual scavenge pumps are gerotor type, fixed displacement pumps. They are located in the upper right hand corner of the main housing. A single gear drives the oil pressure pump. A quill shaft from the pressure pump drives the scavenge pumps. A quill shaft from the pressure pump is also responsible for driving the fuel pump and fuel control.

The discharge of the dual scavenge pumps is joined from a common outlet on the front side of the gearbox. This provides a convenient port for examining the gears on one of the scavenge pumps. It is a very simple matter to remove the fitting from the scavenge oil discharge, look into the port, and turn the engine through by hand. Obviously, looking at the side of the gear teeth would indicate whether the pump was indeed turning, as it should, and secondly, indications of heavy scoring could verify that foreign objects had been passing through the pump.

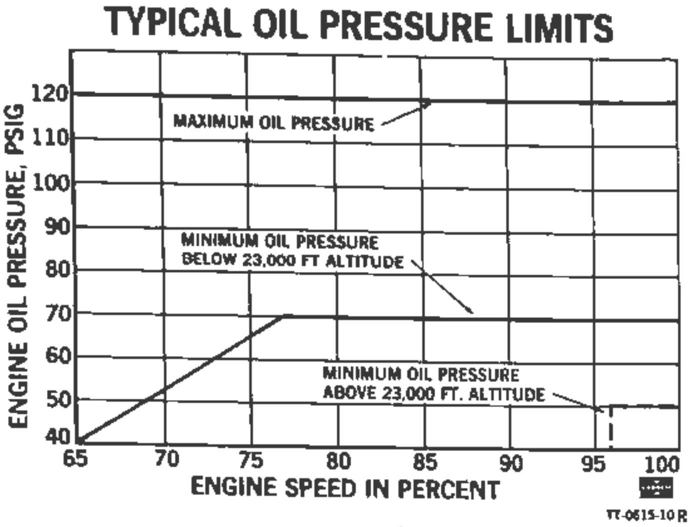
Replacement of these pumps requires the tooling for gearbox disassembly and reassembly.



#365

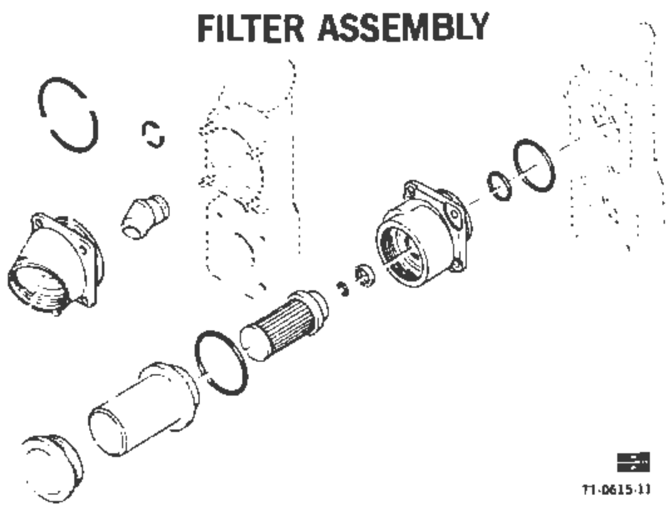
The picture on the left shows the location of the pressure regulator and the filter bypass valves. You'll note the very similar appearance of the two valves. The major difference is the red poppet button that can be seen in the middle of the filter bypass valve. The valves cannot be improperly installed due to the different bolt size. The adjustment to these valves is made by shimming a spring, and no maintenance should be required.

The filter bypass valve serves a unique function in warning the operator that the filter bypass has been opened, probably because the filter is getting restricted. Any time a differential pressure across the filter exceeds a calibrated value, the ball will overcome spring tension and move to the right. As it does, it will extend a rod as shown in the upper picture. This red rod will stay in the extended position and indicate that the valve has been opened. On each preflight inspection, the pilot or mechanic should observe the position of this red rod. If it's extended, no further running should be done until the filters have been inspected and corrective action taken. It is possible in very cold weather that the high viscosity of the oil may cause the filter bypass button to be pushed out on the initial start. If, after the oil has been warmed, the filter bypass button stays in, you may continue operation.



#366

This curve indicates the typical oil pressure limit indications that will be marked on the typical cockpit oil pressure instrument. It should be noted that engine speed has an effect on the oil pressure available. This is obviously due to pump speeds. Notice that engine rpm across the bottom of the curve indicates that oil pressure at ground idle speeds of 65 per cent will be identified by a minimum limit of 40 psi. With engines at speeds above the 80 per cent level, we would expect pressures to range between 70 to 120. On the right hand lower part of the curve, you can see that when the aircraft is flying above 23,000 feet altitude, a new minimum level of 50 psi is permitted. The final authority in this regard is the Pilot's Operating Manual.

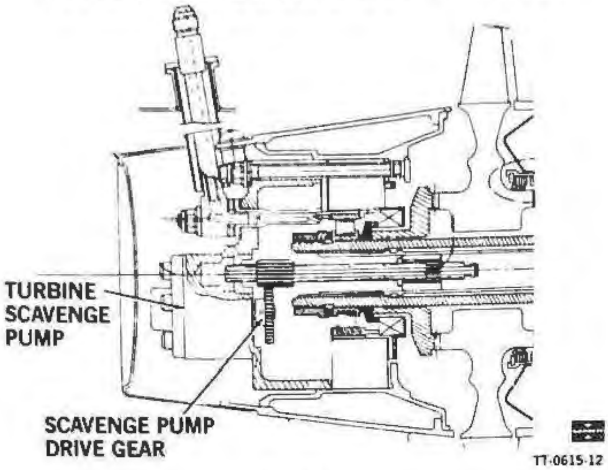


#367

The oil filters on the 331 Engines are located on the right side of the case, below the fuel control. All models of the 331 use a replaceable paper filter. It can be noted in the lower picture that the cover over the filter is attached by a packing nut and sealed with an O ring. There is a sign on each of the oil filter covers cautioning the mechanic only to hand tighten these packing nuts. If there is a leak, it is a matter of replacing an O ring, not tightening the nut.

The illustration on the upper left shows an angled adapter for the oil filter housing. This is used on some models where clearance between the oil filter housing and adjacent parts may be a problem.

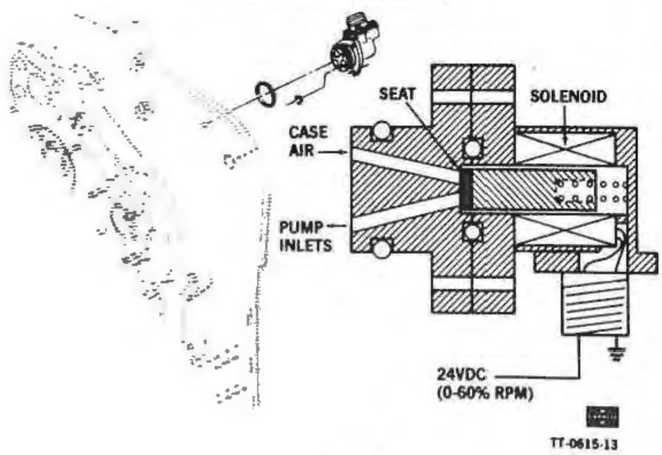
TURBINE BEARING LUBRICATION



#368

Lubrication of the very important turbine bearing is obtained through an external oil line from the accessory case connected to the fitting shown in the upper portion of this picture. That oil is ducted into the jet that lubricates the main rear roller bearing. It also provides oil pressure to the outer race of that bearing to provide a hydraulic mount. The hydraulic mount consists of the oil surrounding the outer race of the bearing keeping the bearing centered and minimizing the transmission of vibration between the high speed rotating group and the fixed members. Also located in the rear cavity is a scavenge pump driven by the main rotating group. It is a small gerotor type fixed displacement pump that turns at about 14,000 rpm. This pump moves the oil from the rear sump through the center of the quill shaft and torsion shaft into the main sump of the gearbox.

OIL VENT VALVE



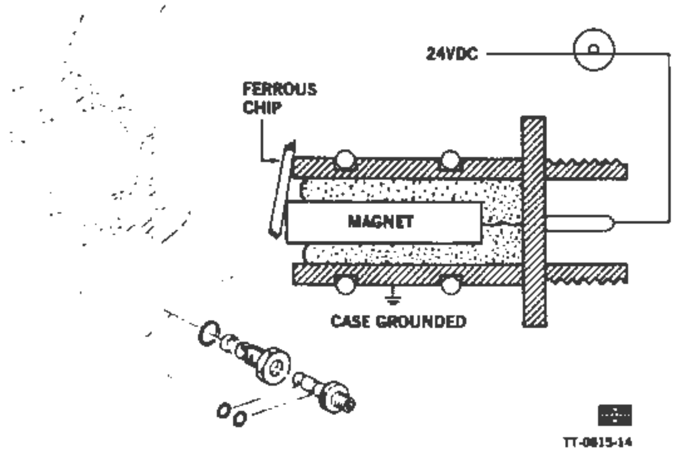
#369

As we examined the simplified schematic of the lubrication system, we discussed the oil vent valve providing air to the main pressure and dual scavenge pump assemblies during the start cycle. This is necessary to reduce the load absorbed by those oil pumps during the start cycle. When the start is initiated, electrical power is supplied to the solenoid on the oil vent valve which moves the armature and the seat to the right. The air inside the gearbox will be ported directly to the pump inlets. During this period of time, the pumps will pump oil and air mixed together. As the engine accelerates above 60 per cent rpm, the speed switch removes the electrical power from the oil vent valve solenoid.

The armature is spring loaded closed and seals the case air from the pump inlets. This should be recognized in the cockpit by a sudden increase in the oil pressure, since the pump begins pumping a solid column of oil, rather than a mixture of air and oil.

It can be seen in the picture on the left, that the oil vent valve is mounted on the forward end of the gearbox in the upper right hand corner.

MAGNETIC CHIP DETECTOR



#370

The chip detector is located in the lower forward sump area. It is usually a bayonet type detector that can be removed from the housing by pressing in and turning counterclockwise. The chip detector has a single pin electrical connector. The chip detector consists of a permanent magnet that is wired to the single pin connector. Whenever a ferrous chip of material would be held by the magnet and complete a circuit to the housing, it would turn on a warning light in the cockpit. On aircraft that do not use a panel light, the chip detector can then be tested by the mechanic in a simple continuity check on preflight.

If a chip detector warning light should come on during operation, the engine should be shut down. Check your Flight Manual for instructions. Maintenance would consist of filter and chip detector inspection to determine corrective action.

MAINTENANCE ACTIONS

ROUTINE SERVICE

- OIL SUPPLY
  - DO NOT MIX OIL TYPES
  - SCAVENGE CASE BEFORE CHECKING SUPPLY
- FILTER
  - INSPECT ELEMENT
  - MAGNETIC CHIP DETECTOR
- ACCESSORY DRIVE SHAFTS LUBRICATION
  - STARTER-GENERATOR
  - TACH GENERATOR
  - ACCESSORY DRIVE-HYDRAULIC PUMP
- S.O.A.P.
  - SPECTROMETRIC OIL ANALYSIS PROGRAM

TT 0615 15

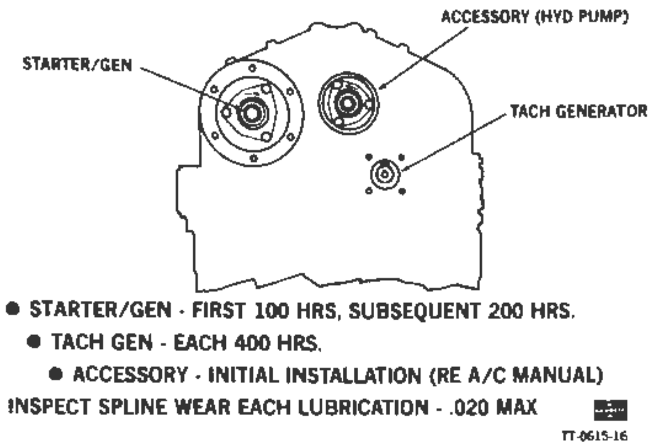
#371

This list is a reminder of some of the routine service maintenance actions described in the maintenance manual.

The manual advises not to mix oil types. When changing from one type to another, there is a procedure for flushing the system. When checking the oil supply level, the gearbox should be scavenged of the oil that may be in the sumps. If the unfeathering pump had been used to put the propeller on the locks, the oil is not returned to the tank because the scavenge pumps are not running. The oil should be returned to the tank before checking quantity. This can be done by either manually turning the propeller in a normal direction of rotation, or by initiating the start switch and cranking it without lightoff.

Filter inspection and magnetic chip detector inspection have been previously discussed. The next few illustrations will deal with drive shaft lubrication and the Spectrometric Oil Analysis Program.

ACCESSORY SHAFT LUBRICATION

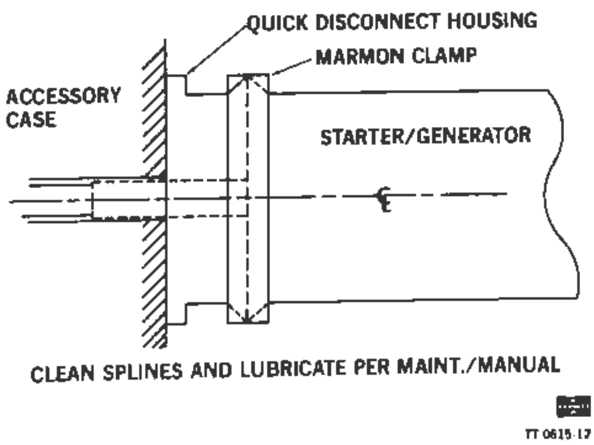


#372

There are three accessory pads on the case that are lubricated by the application of grease. These are not lubricated by the lubrication oil system. The starter generator pad, shown in the upper left, should be greased at the first 100 hours and each subsequent 200 hours. The inspection procedure calls for greasing the tach generator drive each 400 hours. The upper center pad is normally used by the aircraft manufacturer to drive a hydraulic pump or some other aircraft accessory. Greasing instructions for this drive are found in the aircraft manuals.

Inspection of these splines should be done each time they are lubricated. Maximum wear dimensions are specified in the manual. Log book entries should be made when these operations are accomplished.

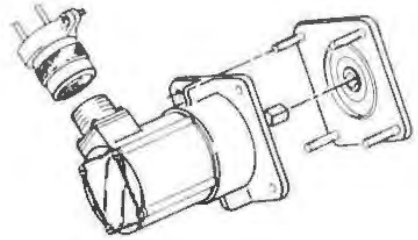
SPLINE WEAR



#373

This picture shows the typical installation of the starter generator. In most cases, a quick disconnect housing will be utilized so that the starter generator is attached to the housing by a marmon clamp. It is important at the inspection periods to clean and inspect these splines for condition prior to greasing and installation. The quick disconnect housing and starter mating surfaces should be cleaned to minimize any wear as a result of misalignment of the splines.

TACH GENERATOR



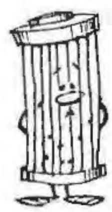
TT-0615-18

#374

Even though the tach generator is an aircraft installed item, it is listed on the engine inspection chart for service every 400 hours. The tach generator has a square drive shaft and square female in the mounting pad drive shaft. At the time of installation, the mechanic must be careful to properly engage the square drive before attempting to bolt the tach generator in place.

SOAP

SPECTROMETRIC OIL ANALYSIS PROGRAM and FILTER CONTENT EVALUATION



TT0413-1

#375

One of the preventative maintenance items highly recommended by Garrett is the accomplishment of the S.O.A.P. program. "S.O.A.P." stands for "Spectrometric Oil Analysis Program."

AS WEAR OCCURS IN THE ENGINE'S OIL WETTED PARTS, METALIC WEAR PARTICLES ARE RELEASED INTO THE OIL SYSTEM.

EXTREMELY FINE PARTICLES REMAIN SUSPENDED IN THE OIL (NORMAL ATTRITION)

COARSER PARTICLES ARE TRAPPED AND RETAINED BY THE FILTER (RAPID WEAR)

110413-2

#376

The analysis of the oil condition in the engine can be divided into two basic areas. First of all, extremely fine particles of material are held in suspension in the oil. These can be chemically analyzed to indicate what part of the engine they are coming from, and if a potential problem may exist.

The larger contaminants are trapped and retained by the filter. The analysis of these larger particles is another important part of the S.O.A.P. check.

The basic contents of the S.O.A.P. kit include: containers for retaining samples of oil taken from the oil tank and the oil filter element and instructions on how to accomplish the sampling, as well as the necessary record keeping that make the examination meaningful.

The siphon tube is injected into the tank to take the sample from the middle of the tank supply of the 331 Engine. The instructions will identify the need for running the engine shortly before taking a sample so that the oil is warm and the particles are still held in suspension in the oil sample.

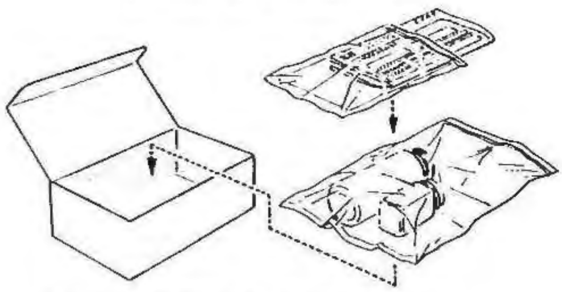
CUSTOMER INFORMATION

TT-0615-21R

#379

The value of chemically analyzing the content of the oil supply in the engine is predicated primarily upon the history of that engine prior to, and including, the time that the S.O.A.P. sample is taken. This form is part of the kit and must be properly completed by the customer for the results of the analysis to be meaningful. The company, street, name and address, type and serial number of the aircraft, hours on the filter since last change, the date of this sample, engine model, time and serial number, hours since the last sample was taken, amount of oil added since the sample was taken, and the engine hours since the last complete oil change, are all required to properly analyze the contents of your oil sample.

SOAP INSTRUCTIONS



INSTRUCTIONS INCLUDED WITH KIT COVER:

- TAKING OIL SAMPLE AND FILTER
- COMPLETE SHIPPING FORM
- SHIPPING INSTRUCTIONS
- ANALYSIS REPORTING PROCEDURES

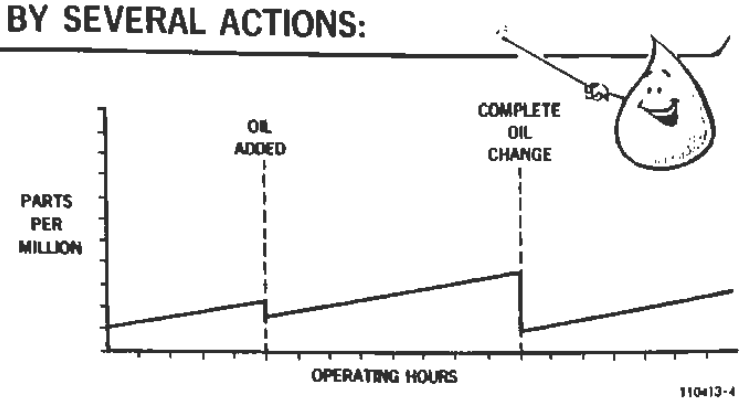
TT-0615-22

#380

The instruction sheet included in the S.O.A.P. kit stresses the correct method of taking an oil sample and the filter, how to complete the shipping form, and how to pack and ship. These instructions are important, since on several occasions, the customer has improperly packaged the S.O.A.P. sample. This resulted in the package leaking oil all over the U.S. mails and the samples were thrown away by the U.S. Postal Service.

The last item on this list is relative to the analysis reporting procedures. If the analysis reveals a condition that must be corrected quickly, the customer will be advised by return telephone call or telex. If the situation is normal, then the results of the analysis will be reported by mail.

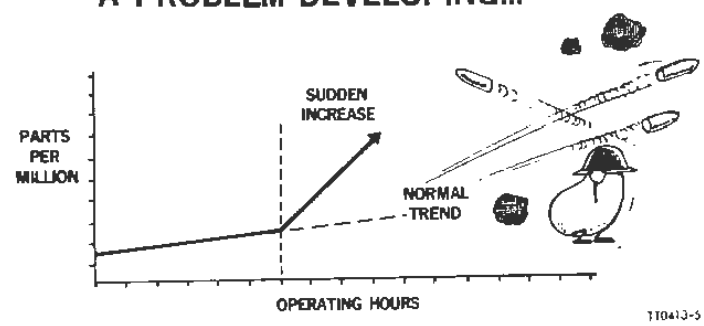
THE "NORMAL" INCREASING TREND OF METAL CONCENTRATION IN THE OIL IS AFFECTED BY SEVERAL ACTIONS:



#382

This curve reveals the need for complete information per the instructions. It can be see here that as operating hours increase and parts per million of some material in the oil tend to increase, that reading can be affected by either the addition of clean oil or, certainly, by a complete oil change.

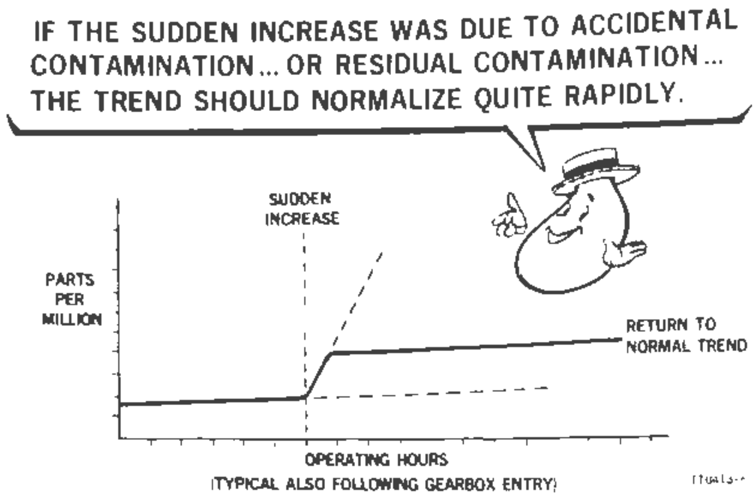
A SUDDEN INCREASE IN METAL CONCENTRATION MAY INDICATE A PROBLEM DEVELOPING...



#383

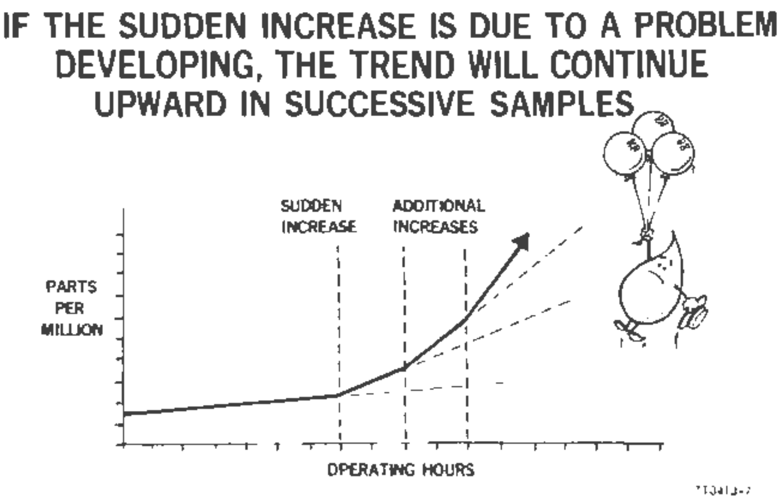
If the analysis of a S.O.A.P. sample indicates a sudden departure from the normal trends that have been established over previous inspections, it may indicate that a problem is developing.

It is also possible that the sudden change in content may indicate that the S.O.A.P. sample was taken improperly. For example, if the S.O.A.P. sample is taken from a supply of oil that has been drained into a dirty container, obviously, the sample will contain the particles that were in the container prior to the oil being drained. In our past experience, we have discovered such things as apple seeds, bugs, cigarette butts and any number of foreign objects that had nothing to do with the engine's lubrication system.



#385

If the sudden increase was due to an accidental contamination, the trend would normalize on the following S.O.A.P. test.



#386

If the upward trend in contaminants continued in successive samples taken at short periods of operation, this would then verify a developing problem with the engine.

FILTER CONTENT ANALYSIS

- FILTER IS BACK FLUSHED AND CONTENTS ARE COLLECTED FOR EXAMINATION.
- THE CONTENTS ARE WEIGHED AND COMPARED TO TIME ON THE FILTER.
- SIZE AND SHAPE OF THE PARTICLES PROVIDE IMPORTANT CLUES AS TO THE SOURCE.
- THE FILTER RESIDUE IS SPOT TESTED CHEMICALLY TO DETERMINE THE ELEMENTS AND ALLOYS PRESENT.

#387

In addition to chemically analyzing the contents of the oil, it is equally important that the contents of the filter by analyzed. The filter is back flushed so that the contents can be removed from the filter for examination. This includes weighing the samples so that you can get a reference as to the rate of contamination. The size and shape of the particles and the type of material will be chemically analyzed so that it can be pinpointed to the specific area in the engine.

The key that makes S.O.A.P. sampling an efficient preventative maintenance action is the record keeping and noting of trends from previous records.

S.O.A.P. SUMMARY

S.O.A.P. IS A USEFUL PREVENTIVE MAINTENANCE TOOL TO UTILIZE FOR MONITORING THE ENGINE'S CONDITION. IT CAN HELP PREVENT EXTENSIVE DAMAGE BY EARLY WARNING.

#389

S.O.A.P. analysis is a good example of preventative maintenance. The ability of the S.O.A.P. analysis program to locate impending failures is directly related to a religious adherence to an entire program. It is important to take samples frequently enough so that trends can be established. It does no good to run an occasional sample and try to base an analysis on that single sample. Samples of oil from your engine could be sent to any chemical laboratory around the world for analysis. However, the important item to consider is that the analysis is not complete unless it is made with regard to the engine itself. An intimate knowledge of the engine is necessary in order to identify where the particular material may be coming from and how serious the problem may be.

S.O.A.P. LABORATORIES

REF: SIL P331-97 JAN 1979

PHOENIX, ARIZONA
OAKLAND, CALIFORNIA
ATLANTA, GEORGIA
BALTIMORE, MARYLAND
ST. LOUIS, MISSOURI
LINDEN, NEW JERSEY
LAS VEGAS, NEVADA
STAFFORD, TEXAS
RAUNHEIM, GERMANY
TOKYO, JAPAN
BANGKOK, THAILAND

#390

This is a list of the locations of laboratories that are qualified by Garrett to interpret the results of their chemical analysis as it relates to the 331 Engine. The Service Information Letter identified here should be referred to for changes to this address list. These facilities have personnel trained to recognize the types of materials used in the various places throughout the 331 Engine and will be in an excellent position to investigate the analyzed sample and relate it to action that needs to be taken.

MAINTENANCE ACTIONS

CORRECTIVE MAINTENANCE

- EXCESSIVE CONSUMPTION
  - AIR/OIL SEPARATOR NEEDS CLEANING
    - COMPRESSOR - OIL IN INLET
    - TURBINE - OIL IN EXHAUST - SMOKE
    - SEAL LEAKS
- HIGH OIL TEMPERATURE
  - RESTRICTED OIL COOLER AIRFLOW
  - OIL DILUTION WITH FUEL
  - INDICATION SYSTEM
- LOW OIL PRESSURE
  - EXTERNAL LEAKS
    - PLUMBING, SEALS
  - INTERNAL LEAKS
    - PACKINGS, GASKETS
  - INDICATION SYSTEM

#391

In addition to the routine maintenance actions previously described, you should consider some corrective maintenance as it applies to troubleshooting the lubrication system. This maintenance can usually be broken down into three major areas.

Excessive consumption is usually caused by an air/oil separator that needs cleaning, or by leaks. Compressor seal leaks will be evident by oil dripping into the inlet of the engine when the engine is static on the ground. Oil leaking through the turbine seal is usually evidenced by oil vapor in the exhaust causing smoke, or the exhaust duct may be wet with oil. Corrective action in either case would be to replace the seals according to the maintenance manual.

High oil temperature can be the result of a restriction to the airflow across the oil cooler. Oil dilution with fuel may cause a high temperature. The most likely candidate for this problem would be the fuel heater. If the fuel heater has a leak, the higher fuel pressure would obviously leak into the oil supply. This would be evidenced by too much oil in the tank and fuel mixed with the oil. A temperature problem can also be a matter of the indication system.

Low oil pressure is another major area of consideration. External leaks are usually easy to find because the oil is dripping from some part of the engine. Internal leaks may be caused by O ring packings or gaskets. The indication system can be double checked by hooking a direct reading gage to the pressure measuring port right above the oil filter assembly.

SUBJECT: WORKBOOK EXERCISE 8
SECTION 10 - LUBE SYSTEM

1. Checking the engine oil supply before flight indicated the oil level was below the "add oil" mark on the dipstick. The first corrective action would be:
   a. Add the amount of oil required to bring the level to the "full" mark.
   b. Ground run the engine to check oil pressure. No additional oil is needed if the oil pressure is above the minimum limits.
   c. Leave the oil level alone until after the next flight and then recheck the quantity and service as necessary.
   d. Crank the engine, recheck the oil level and service as necessary.

2. The need for cleaning the air/oil separator may be indicated by:
   a. An increasing oil tank supply level.
   b. Excessive oil vapor discharged from the separator vent to atmosphere.
   c. A higher than normal oil pressure gage reading.
   d. Oil dripping from the turbine exhaust duct after engine shutdown.

3. The indication of a restricted oil filter would be:
   a. Zero oil pressure gage indication.
   b. Lower than normal oil pressure gage indication.
   c. Higher than normal oil pressure gage indication.
   d. Filter bypass valve indicator extended.

4. Assume that the quill shaft between the oil pressure pump and the dual scavenge pump assembly broke during engine operation. The first cockpit indication of this problem would be:
   a. The propeller would NTS.
   b. A sudden loss of fuel flow.
   c. The oil pressure gage would drop to zero.
   d. A rapid increase in oil temperature indication.

WORKBOOK EXERCISE 8

5. Normal operation of the oil vent valve can be determined from cockpit instruments by observing:

   a. First indication of oil pressure at 60% rpm.
   b. A sudden decrease in oil pressure at 60% rpm.
   c. A sudden increase in oil pressure at 80% rpm.
   d. A sudden increase in oil pressure at 60% rpm.

6. An internal leak occurred in the fuel heater heat exchanger. This would result in:

   a. An increased oil level in the tank.
   b. Higher than normal oil pressure.
   c. Lower than normal oil supply level in the tank.
   d. The engine failure to light off due to oil contamination of the fuel system.

7. The trend of metal contamination of the oil determined during SOAP analysis may be affected by:

   a. Adding a quart of oil to the supply.
   b. Changing oil at a recommended inspection period.
   c. Submitting for analysis an oil sample from the sump area of the tank.
   d. All of the above.

SECTION ELEVEN:

MISCELLANEOUS SYSTEMS -

PNEUMATIC AND IGNITION

PNEUMATIC SYSTEMS

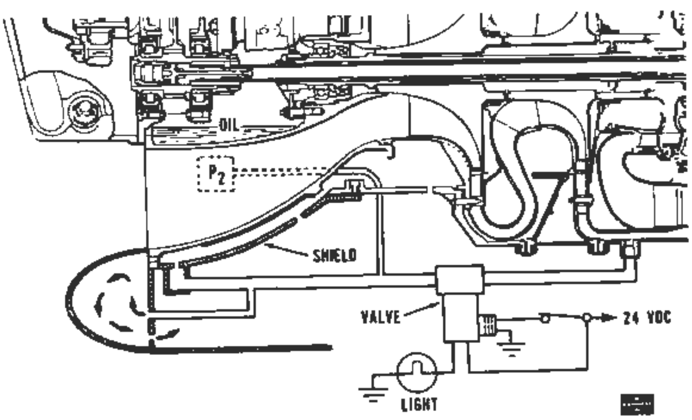
- ENGINE ANTI-ICING
  - COMPRESSOR INLET
  - P_2 SENSOR
  - NACELLE LEADING EDGE
- BLEED AIR SOURCE FOR:
  - AIRCONDITIONING/PRESSURIZATION SYSTEMS
  - FUEL MANIFOLD PURGE SYSTEM
  - P_3 SIGNAL TO FUEL CONTROL

TT-0616-3

#395

The two pneumatic systems that will be described here include the engine inlet anti-icing system and the bleed air system. Engine anti-icing includes the compressor inlet area, the P_2 sensor, and a customer connection for engine nacelle leading edge anti-icing. The bleed air systems are used for controlling air taken from the compressor section of the engine for air conditioning and pressurization of the aircraft and also the air utilized by the engine for the fuel manifold purge system and as a P_3 signal to the fuel control.

ENGINE ANTI-ICE SYSTEM



TT-0616-4 R

#396

Included with all 331 Engines is an inlet anti-icing system. Proper utilization of this system will allow the pilot to fly in known icing conditions. It is important to recognize that anti-icing is the prevention of ice from forming. A de-ice system is a means to eliminate the ice once it has been formed. This system on the 331 is designed primarily as an anti-ice system. Should the pilot recognize the need for de-icing, he must follow the cautionary notes in the Pilot's Operating Manual on the de-ice procedure. This involves turning on the system on only one engine at a time. Normally, this system is used as an anti-ice system and the pilot should activate the system on both engines as he enters a known icing condition.

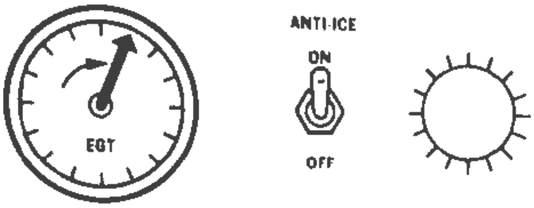
It can be seen from this simplified schematic that the air is taken from the compressor discharge. When the pilot has activated the switch in the cockpit and opened the anti-ice valve, the hot air is made available to the inlet shield. The hot air flows between the shield and the inlet housing of the engine. It escapes through the holes back into the nacelle area and is discharged overboard.

As that hot air flows past the inlet housing of the engine, it heats the housing and prevents ice from forming. The top part of the inlet housing will be heated by the warm oil that is in the gearbox. The small line provides that warm air to the P_2 sensor to keep it from being clogged with ice.

This picture also shows air being permitted to flow into the D-duct section of the nacelle mounted to the inlet. Flowing through the duct and discharging back into the nacelle, it transfers heat to the aluminum skin preventing ice from forming.

There is a panel light in the cockpit to indicate when the anti-ice valve is in the open position.

ANTI-ICE OPERATIONAL CHECK



ANTI-ICE SYSTEM "ON" = • INDICATOR LIGHT ON
• EGT
OBSERVE FLIGHT MANUAL GROUND CHECK LIMITS

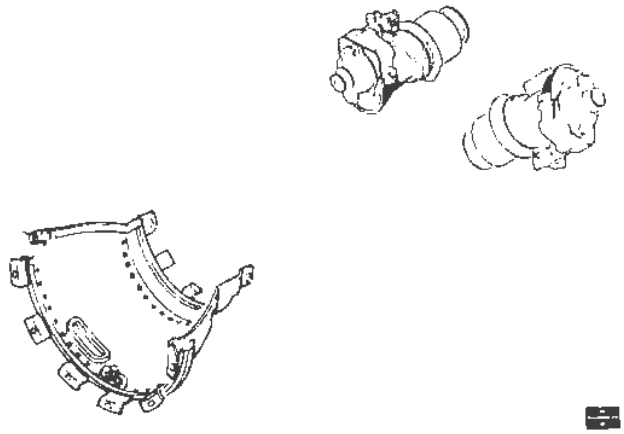
TT-0618 5R

#397

A simple operational check can be accomplished on the inlet anti-ice system either in flight, or on the ground. This check is based upon the fact that bleeding air from the compressor discharge represents a reduction in power capabilities of the engine. When the anti-ice switch is placed in the "ON" position, there will be two indications. The indicator light should come on in the cockpit and a rise in EGT will be seen. If the light does not come on, but you still get an increase in EGT, this indicates there is a problem in the indicator light system. The valve is actually opening as indicated by the EGT rise.

The flight manuals will limit the operation of this system on the ground--when the ambient temperature is above 40 degrees Fahrenheit--to a limit of 10 seconds of operation. This is to prevent bleeding excessive hot air to the inlet area that may damage the parts by causing first stage compressor rub against the shroud.

INLET ANTI-ICE SHIELD

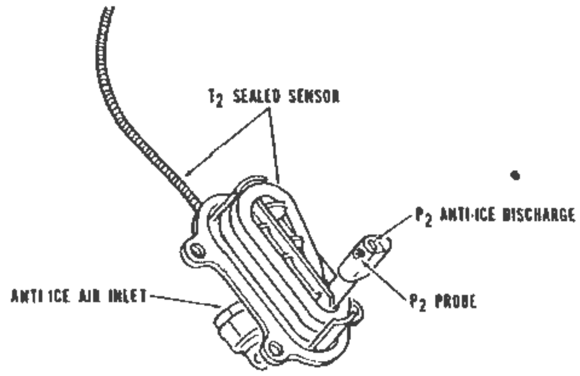


TT-0616-6

#398

The inlet anti-ice shield is formed to fit around the inlet section of the gearbox of the engine. This is true whether the inlet is down or up, as shown here. The shield is constructed so that there will be a space provided between the shield and the inlet housing. The row of small holes on the forward edge of the shield shows where the air comes into the shield. It discharges out the small holes on the aft side of the shield. This air does not enter the compressor inlet, it is discharged into the nacelle area and back to atmosphere.

P_2 SENSOR ANTI-ICE

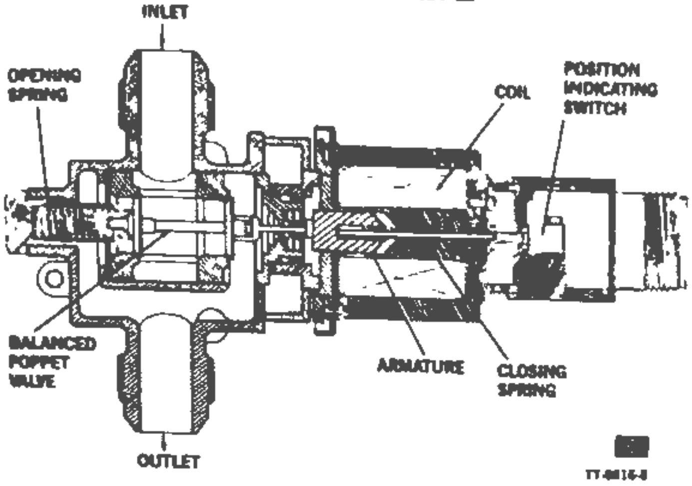


TT-0616-7

#399

The T_2 P_2 sensor is mounted on the right side of the compressor inlet duct. The section protruding into the inlet air passages includes the P_2 sensor, which is a ram probe facing into the inlet stream. Hot bleed air from downstream of the anti-ice valve is plumbed to the fitting shown on the left. As the warm air flows to the discharge port, it warms the probe to prevent ice formation. The small amount of P_2 anti-ice air that discharges into the compressor inlet has no effect on the temperature of the air going into the engine.

ANTI-ICE VALVE



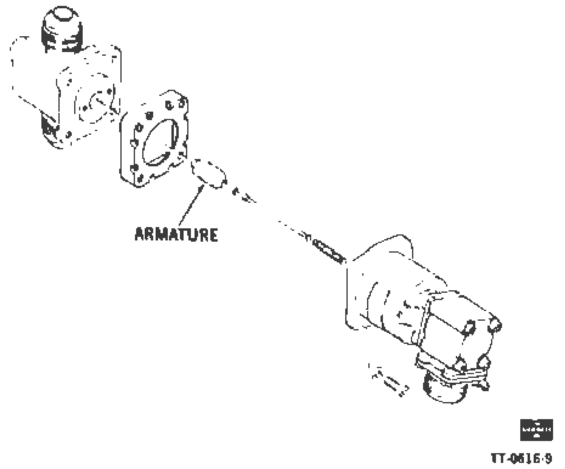
#400

The anti-ice valve is a balanced poppet valve. The principle of the balanced poppet valve permits the use of very light springs to open or close the valve. Air entering the inlet port would bear against the poppet on the left, attempting to push it on to the seat. The same pressure bearing on the poppet valve on the right would attempt to push that valve off the seat. Since the two poppets are on a common shaft, they are designed to be balanced as a result of those forces. As shown here, the valve is in the closed position because the closing spring on the right side is stronger than the opening spring on the left side.

When the valve is operated by the switch in the cockpit, 24 volt power is sent to the coil, creating a magnetic field that attracts the armature. As the armature moves to the right, it compresses the closing spring and removes that force from the poppet valve assembly. The opening spring is now strong enough to move the poppet to the right, opening both ports and allowing the compressor discharge air to flow through the poppets to a common outlet shown on the bottom of the valve.

As the armature is stroked to the right, a pin will activate a position indicating microswitch. That is the switch that will turn on the light in the cockpit showing that the valve is open.

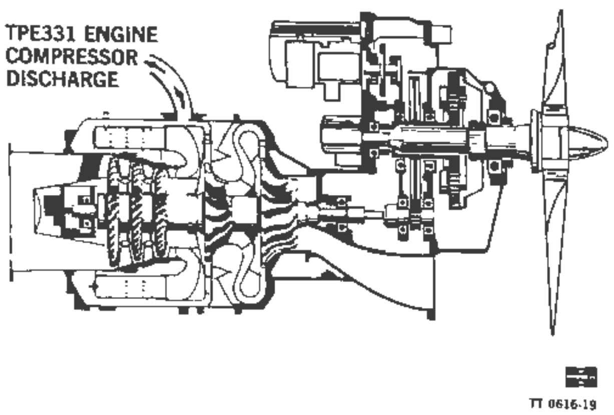
VALVE MAINTENANCE



#401

Let's assume that the pilot has activated the switch in the cockpit to operate the anti-ice valve. The light did not come on and he saw no change in EGT. This is a good indication that the valve itself did not open. The electrical circuit should be checked for 24 volts at the connector on the valve. If it still won't open, the armature may be sticking. Corrective action that may be taken--following the instructions in the manual--is to disassemble the valve, as shown here. The armature may be cleaned with a very fine grade of crocus cloth and reinstalled. It should be kept clean; no grease or lubrication should be applied. It is not recommended that the valve body itself be disassembled in the field.

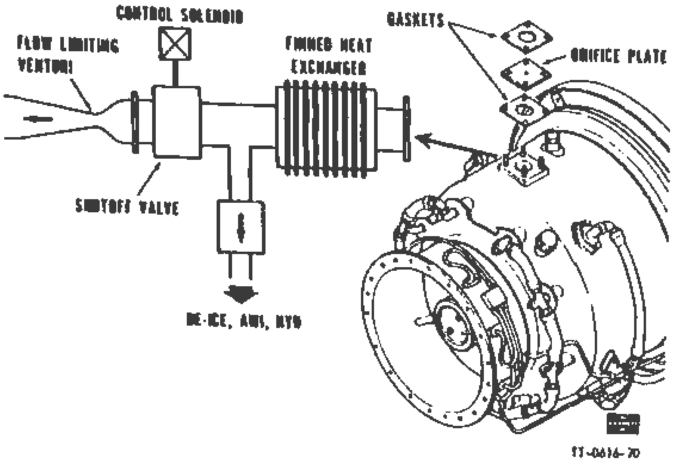
SOURCE OF AIR



#402

Pneumatic power is bled from the 331 Engine for use in other systems, in addition to the inlet anti-ice. It is used for the air conditioning and pressurization system, the fuel manifold purge system, and as a pneumatic signal to the fuel control unit. It is obvious that the amount of air bled from the machine must be limited in order to prevent excessive loss of power. Typically, the bleed is limited to approximately 8-10 per cent of the total through-flow of air.

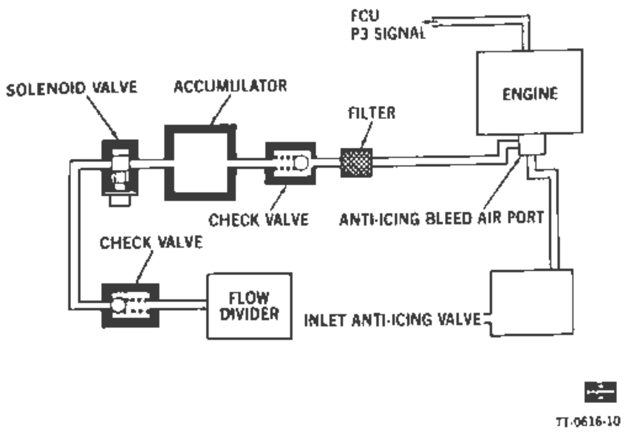
PRECOOL AND FLOW LIMITING



#403

This schematic shows a portion of the ducting that provides engine bleed air to the air conditioning system, as well as some auxiliary systems of de-ice, alcohol water injection and possibly hydraulic systems. Some aircraft will cool this air through the use of the heat exchanger. The flow limiting venturi is part of a shutoff valve that will limit the flow taken into the system within the specifications of engine bleed. Notice that the mounting pad on the plenum chamber for the ducting system includes an orifice plate with a gasket on either side. The hole in the orifice plate is precisely calibrated to limit the bleed from the engine within the specified tolerances, in the event that a massive leak should occur in the aircraft ducting. This would prevent overbleeding the engine. Since the orifice plate has a gasket on both sides, torquing procedures are very critical. When the duct is installed to the plenum chamber with the orifice plate and gaskets in place, the maintenance manual torque value should be observed. Tighten the nuts down alternately to maintain an even force on the gaskets. This will prevent the gaskets from blowing out and causing a substantial leak.

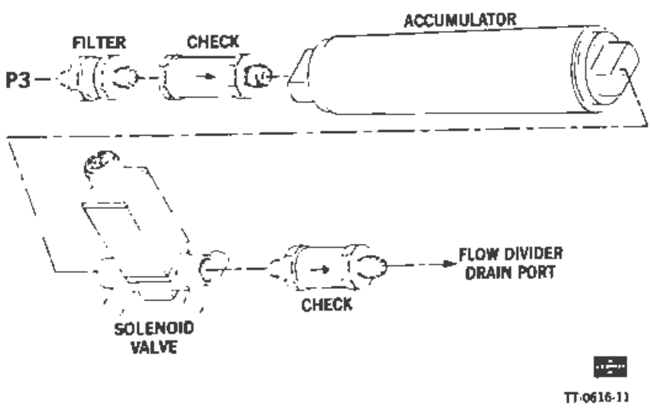
FUEL MANIFOLD PURGE SYSTEM



#404

The P_3 air bled from the engine to provide pneumatic power for the other systems is taken from different ports within the plenum chamber. The fuel control P_3 signal is taken from a bulkhead fitting, generally located near the top of the plenum chamber. The fuel manifold purge system usually takes air from the same port that supplies the inlet anti-ice valve. The fuel manifold purge system was discussed in the fuel section.

PURGE SYSTEM COMPONENTS



#405

This picture illustrates the appearance of the components in the fuel purge system and also shows their relative location. Starting at the upper left, the P_3 air supply is provided through the filter element and a one-way check valve with the arrow pointing towards the accumulator. As the air leaves the accumulator, it's available to the electrically operated solenoid valve. This check valve located downstream of the solenoid valve has the free flow arrow pointing toward the flow divider.

MAINTENANCE ACTIONS

- **ANTI-ICE SYSTEM**
  VALVE ELECTRICAL OPERATION
  VALVE CLEANING
- **BLEED AIR SYSTEM**
  PLENUM ORIFICE PLATE INSTALLED
  CORRECT TORQUE PROCEDURES
- **FUEL MANIFOLD PURGE SYSTEM**
  FILTER CLEANING
  VALVE ELECTRICAL OPERATIONS
  CHECK VALVE INSTALLATION

#406

All pneumatic systems will require the usual plumbing and fitting security checks.

The anti-ice system may require an electrical check of the anti-ice valve and, on occasion, it may be necessary to clean the armature in the valve if it fails to open.

In the bleed air system, the plenum orifice plate installation with correct torque procedures is very important.

The fuel manifold purge system filter should be periodically cleaned according to maintenance manual procedures.

The shutoff valve electrical operation may be checked and the one-way valves must be properly installed.

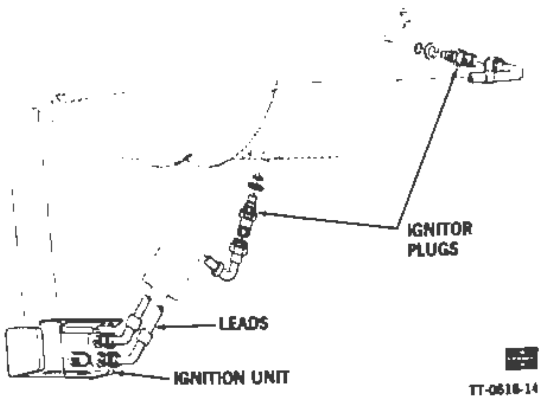
IGNITION SYSTEM

- **HIGH ENERGY IGNITION UNIT**
- **LEADS**
- **IGNITOR PLUGS**

#407

Ignition systems in a turbine engine must meet a very peculiar requirement. The familiar spark plug and magneto of a reciprocating engine will not suffice in a turbine engine atmosphere. A spark plug fires on each cycle in a reciprocating engine, but the turbine engine provides constant combustion once the fire has been lit, during the start procedure. During the major portion of the turbine operation, the ignitor plug is not operating and is more susceptible to carbon contamination. The ignition system for the 331 Engine is of the high energy type. It is a capacitor storage system, discharging high amperage, as well as voltage, in order to cause a spark to occur in an ignitor that has been heavily contaminated. The 331 Engine utilizes a high energy ignition unit supplying two leads connected with two ignitor plugs.

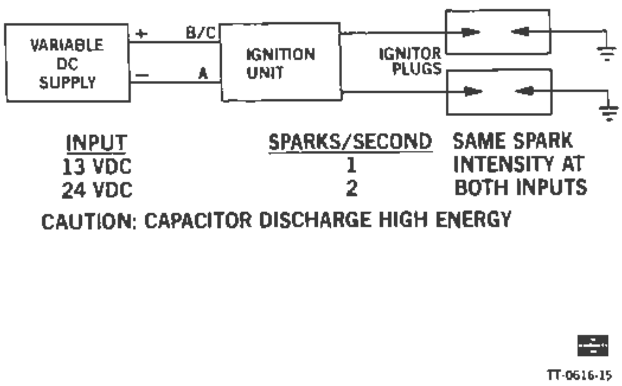
IGNITION SYSTEM



#408

This picture offers a view of the typical installation of the ignition unit on the lower left side of the gearbox. Two shielded high tension leads connect the ignition unit to the two ignitor plugs installed in the plenum chamber at various locations.

IGNITION UNIT CHECK

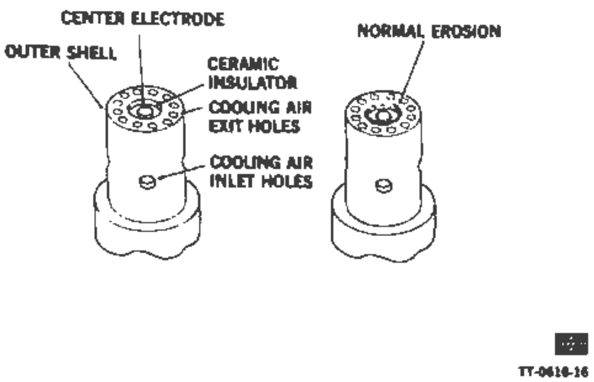


#409

The only maintenance checks indicated in the manual for the ignition unit will be to visually check its condition and to operationally check the unit for proper output. This simple schematic shows a variable dc supply being connected to the appropriate pins in the ignition unit. This test should only be conducted with the ignition unit connected to ignitor plugs. If the spark is allowed to jump from a disconnected high tension lead to some ground connection, damage to the parts will occur because of high amperage and voltage involved. With the 13 volt dc input, we would get approximately one spark per second. Increasing the dc voltage should cause an increase in the rate of the sparks; however, in both cases the sparks will be of the same intensity.

The unit contains large storage capacitors. Once the capacitor has been fully charged and triggered to discharge, the intensity of the spark will be the same. The precautions identified in the maintenance manual should be observed in the testing and handling of the high energy ignition unit.

IGNITOR PLUG INSPECTION

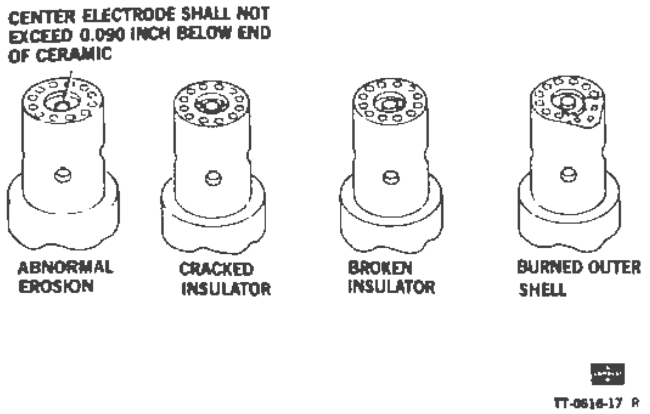


#410

The condition of the ignitor plugs should be visually inspected at routine periods. The picture on the left identifies those major elements to be inspected: the center electrode, the outer shell--which provides the gap for the spark to jump--and a ceramic insulator surrounding the center electrode. These are the three major areas for inspection.

The picture on the right indicates that normal erosion will eat away at the outer shell and can be considered normal up to a point.

IGNITOR PLUG REJECTS



#411

The engine manual provides visual evidence in the inspection section to assist the mechanic in determining the undesirable conditions of the ignitor plugs. The example on the far left shows abnormal erosion to the center electrode and gives a limit that the center electrode should not exceed 90 thousandths of an inch below the end of the ceramic. The second example shows a cracked ceramic insulator. The third one reveals pieces of the ceramic that have been broken away. Finally, the fourth drawing indicates a burned outer shell as evidenced by excessive material lost. These are typical examples of reasons to replace the ignitor plugs.

SUBJECT:
SECTION 11 - MISCELLANEOUS SYSTEMS, PNEUMATIC, IGNITION

WORKBOOK EXERCISE 9

1. To verify operation of the inlet anti-ice (inlet heat) system you should observe:

   a. Illumination of the thermostatically operated inlet heat light.
   b. Illumination of the inlet heat light due to valve operation, accompanied by a loss in power as shown by a rise in EGT.
   c. Illumination of the inlet heat light due to valve operation, accompanied by a loss in power as shown by a decrease in EGT.
   d. An increase in power as shown by a rise in EGT.

2. During engine shutdown, the stop switch was held in the stop position until engine rpm was below 50% but no rise in EGT/rpm was observed at the time the stop switch was actuated. This could be caused by:

   a. Manifold fuel pressure being greater than purge system accumulator pressure.
   b. The flow divider remaining open after shutdown.
   c. Purge system accumulator pressure being equal to P_3 pressure at the time of stop switch actuation.
   d. All of the above.

3. When checking the ignition unit for proper operation, what should be observed as you increase input voltage?

   a. The spark rate remains constant and the intensity increases.
   b. The spark intensity remains constant and the rate increases.
   c. The spark rate decreases and the intensity increases.
   d. The spark intensity decreases and the rate increases.

SECTION TWELVE:

OPERATIONAL CHECKOUT

OPERATIONAL CHECKOUT

- AIRCRAFT AND ENGINE RIGGING
- GROUND RUN CHECK
- FLIGHT CHECK
- INSTRUMENT MATCHING

#415

We have now completed discussion on all of the major systems and components of the TPE331 Engine. In this section, the operational checkout of these systems will be covered, particularly as they apply to twin engine operation.

The first item covered will be the aircraft and engine rigging. This will not be an attempt to teach the details of how to rig the engines. That is a practical activity that will be covered in the maintenance manual. This section will give the mechanic the understanding and ability to verify the correct rigging of the aircraft and the engine.

Secondly, you will be taken through the ground run check procedures identified in detail in the maintenance manual. We will describe those items that will require aircraft test flights in order to accomplish proper adjustment and matching of the engines.

Finally, the subject of matching the engine instruments of the left and right engines will be covered.

RIGGING PRIORITY

1. RIG THE AIRCRAFT (A/C MAINT MANUAL)
2. RIG THE ENGINE (ENGINE M/M)
3. RIG THE AIRCRAFT CONTROLS TO THE ENGINE (A/C M/M)
4. SET PROPELLER FLIGHT IDLE ANGLE (A/C M/M)

#416

There is a definite priority in the mechanical rigging of the aircraft and engine power management system components. For example, if the aircraft is rigged improperly, you cannot correct that situation by changing the rigging on the engine. The first step is to make sure that the aircraft is rigged properly according to the aircraft maintenance manual. Secondly, the engine must be properly rigged to itself. Instructions for this are contained in the engine maintenance manual. Thirdly, the adjustments necessary to properly mate the engine to the aircraft will be part of the aircraft rigging system, and instructions in the aircraft manual should be followed. Finally, with the aircraft and engine properly rigged, the propeller flight idle blade angle can be set, following the aircraft manual procedures.

AIRCRAFT/ENGINE RIG CHECK

POWER LEVER -

CORRESPONDENCE TO PROP PITCH CONTROL AND FUEL CONTROL CAMS

SPEED LEVER -

POSITION FUEL CONTROL UNDERSPEED GOVERNOR AND PROP GOVERNOR SHAFTS RELATIVE TO DESIRED ENGINE RPM IN BETA OR PROP GOVERNING MODE

#417

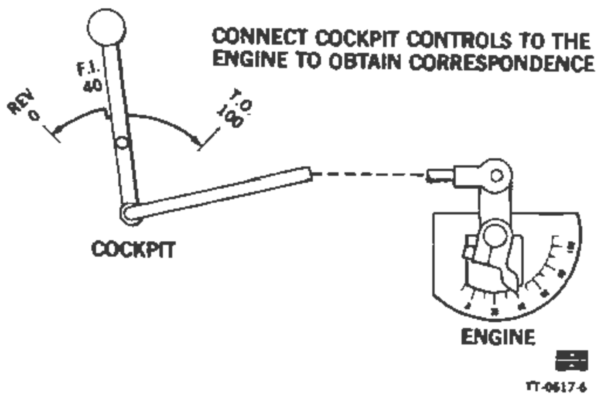
Each engine is controlled by a power lever and speed lever. It is appropriate at this point to review what the mechanical connection to each of these levers must accomplish when properly rigged to the engine.

The power lever must maintain a correspondence to the prop pitch control and the fuel control cams. Previous discussions in the propeller and fuel control systems explained that each of these devices has a cam that must be appropriately positioned by the movement of the power lever.

The speed lever is responsible for positioning the fuel control underspeed governor and the propeller governor shafts relative to desired engine rpm when in either beta or prop governing mode.

Let's first discuss the power lever and how to check its proper positioning of the cams in the prop pitch control and fuel control.

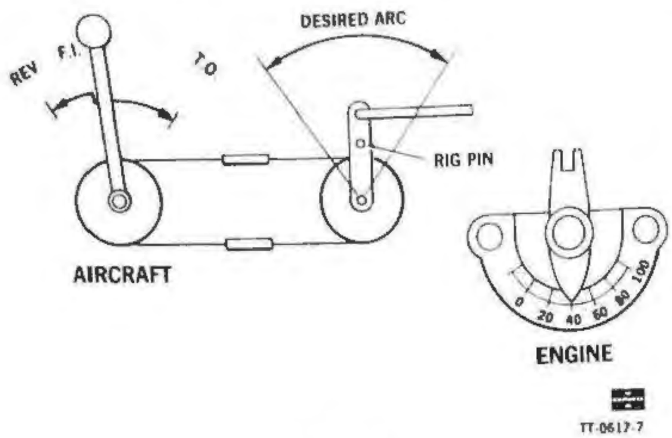
RIGGING OBJECTIVE



#418

The power lever mechanical rigging connects the cockpit quadrant control to the prop pitch control shaft on the engine. The major positions of the power lever are reverse, flight idle and takeoff. This picture illustrates the relative positions in degrees on the protractor, as related to the positions on the power lever. Reverse is zero degrees, flight idle is 40 degrees and takeoff is 100 degrees.

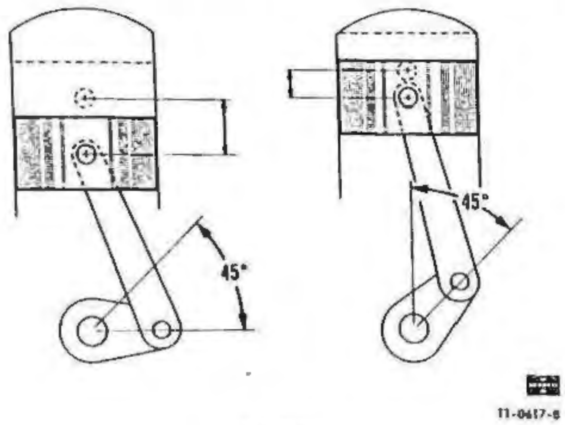
AIRCRAFT RIGGING



#419

Aircraft mechanical rigging systems utilize various types of controls. Pictured here is a typical cable and push-pull system. Many aircraft utilize Teleflex or Controlex shielded systems. Whatever system is used, it is extremely important that the procedures of the aircraft maintenance manual be followed exactly. The proper use of the rig pin in this illustration is necessary to make sure that the lever operates in a desired arc of travel.

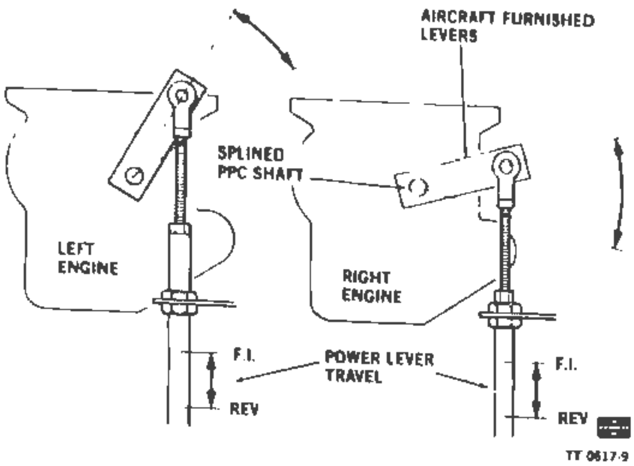
ARC EFFECT ON STROKE



#420

Obtaining the correct stroke for a given amount of rotational travel can be demonstrated by the use of these two drawings. The piston on the left has moved a given stroke dimension as the result of a 45 degree arc of travel indicated on the crank shaft. The picture on the right shows that as the crank shaft moves in a different arc, the same 45 degrees of rotation results in a much shorter stroke.

PPC LEVER POSITION PROBLEM

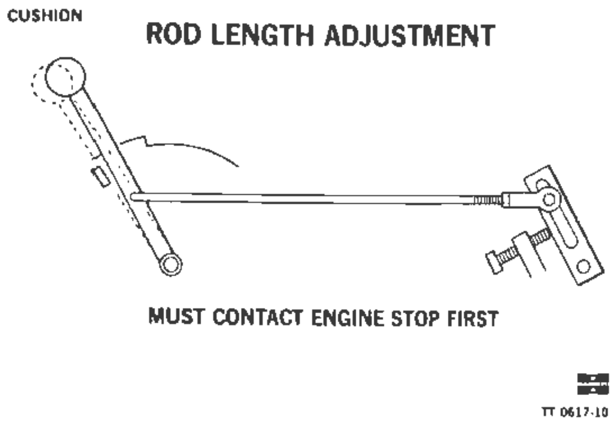


#421

This picture illustrates a very real problem that has occurred on twin engine applications of the 331. This is an illustration of the prop pitch controls on the left and right engines, and the linkage connections from the power levers in the cockpit. The aircraft furnished levers are installed on the spline shaft of the prop pitch control, and can be installed in a variety of positions. In this case, the lever on the left prop pitch control has been positioned in a different arc of travel than the one on the right control. If the power levers for both of these engines were moved the same distance from reverse to flight idle, it would result in a considerably greater arc of travel on the right hand prop pitch control than it would on the left. Consequently, the engines would not be matched in a position of the prop pitch control cams, even though the power levers in the cockpit are matched. The aircraft maintenance manual will describe in detail the correct position of these levers to be installed on the prop pitch control.

POWER LEVER RIGGING

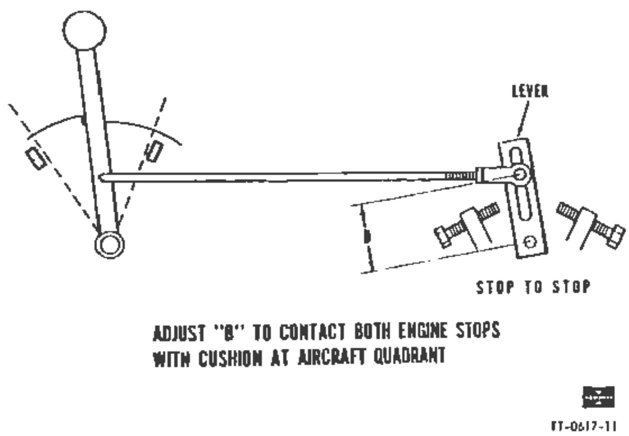
ROD LENGTH ADJUSTMENT



#422

In rigging the aircraft and engine together, it is imperative that the controls are stopped by the limit stop on the engine component before the lever in the cockpit reaches the end of its mechanical travel. This overtravel dimension on the lever in the cockpit is called "Cushion," or "Spring Back." All aircraft maintenance manuals will specify the amount of cushion that should be maintained. With the stop on the engine firmly contacted, the amount of cushion would be a matter of adjusting the length of the rod.

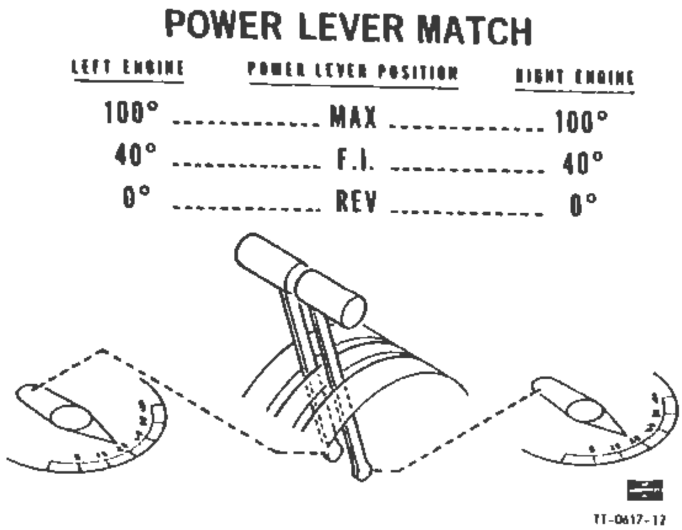
LEVER LENGTH ADJUSTMENT



#423

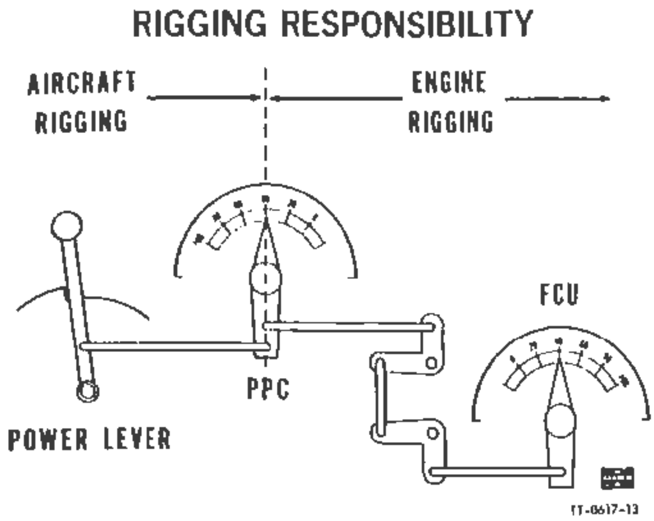
Assume that the rod length has been properly adjusted to contact the stop on the engine, maintaining the proper cushion on the reverse end of the power lever quadrant. Let's also assume that we contacted the mechanical limit of travel of the power lever before we attained the full forward position stop on the prop pitch control. No adjustment to the rod length will correct this problem. Adjusting dimension B will be necessary to change the degree of rotation of the pitch control shaft. Reducing dimension B would result in less movement of the power lever to make stop-to-stop on the engine.

The basic considerations for rigging the power lever to the prop pitch control can be summarized in alternate adjustment to rod and lever length to obtain stop-to-stop travel of the prop pitch control while still maintaining a cushion on both ends of the power lever quadrant.



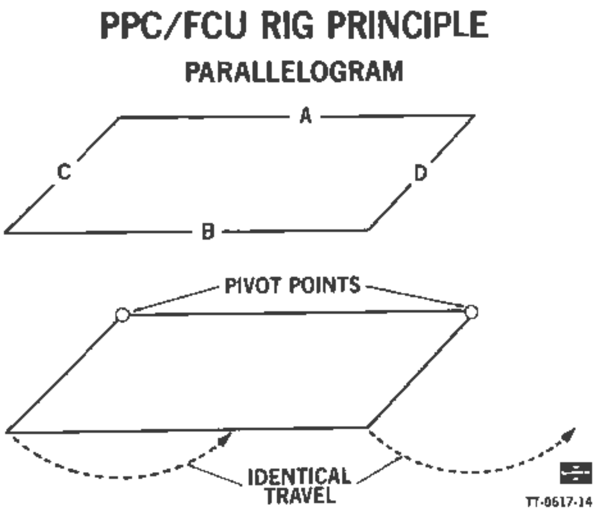
#424

A simple check of the power lever mechanical linkage between the cockpit and the engines is described here. One mechanic should be in the cockpit manipulating the power lever controls while other mechanics are observing the pointer position on the protractor on the prop pitch controls. The mechanic in the cockpit should advance the power levers to the maximum position, noting the correct cushion. At this point, both protractors should register 100 degrees, plus or minus the small tolerances allowed in the maintenance manual. As the mechanic in the cockpit brings the power lever back to the flight idle detent, both protractors should register 40 degrees. As the power levers are brought back to full reverse, the operator in the cockpit should note the cushion, and the engines should register zero degrees on both protractors within the small tolerances allowed in the maintenance manual.



#425

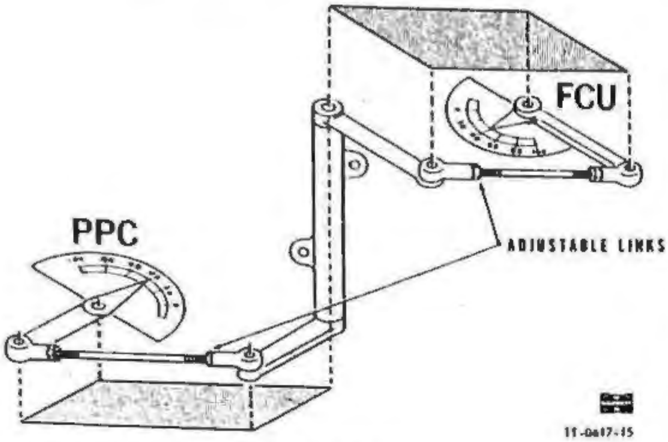
Discussion up to this point has dealt with the aircraft rigging system and obtaining the necessary correspondence between the power lever and the prop pitch control. The engine rigging portion of the power lever system deals with the rigging between the prop pitch control and the fuel control. When the engine rigging has been done properly, movement of the power lever will result in matched readings on both protractors. This establishes the correct relationship between the cams in the pitch and fuel controls.



#426

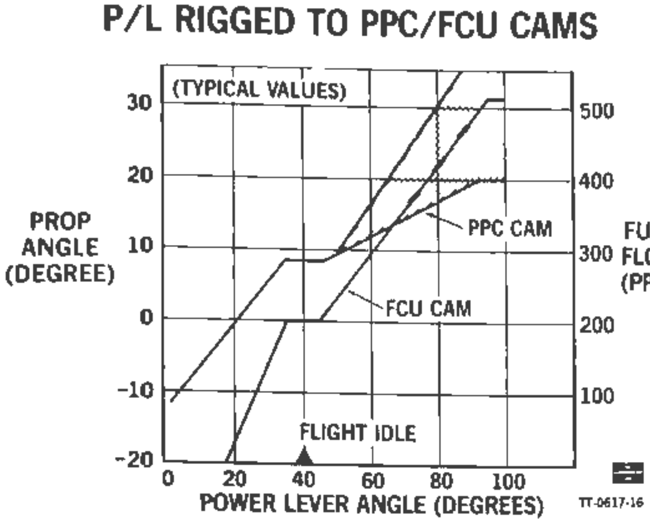
The basic principle involved in the rigging of the engine prop pitch control to the fuel control makes use of a "Parallelogram." A parallelogram is a geometric design in which dimensions A and B are the same, dimensions C and D are the same and yet, there are no 90 degree angles. If you assume that the two points are pivot points, you can see that the parallelogram would cause an identical travel between the two lower intersect points. When one would be moved, the other one would move exactly the same way and the same amount. Rigging of the prop pitch control to the fuel control is an example of this principle.

PPC/FCU PARALLELOGRAMS



#427

This picture illustrates the mechanical linkages involved in rigging the prop pitch control and fuel control together. In the lower left corner, the prop pitch control protractor and pointer can be seen. Visualize a fixed dimension between the center line of the pitch control shaft and the rod end fitting. Compare that to the dimension on the other end of the adjustable link to the center of the concentric shaft. Those two dimensions are identical. The dimension between the center line of the prop pitch control shaft and the concentric shaft is matched by the length of an adjustable link, thus, a parallelogram is established between the prop pitch control and the concentric shaft. The concentric shaft is a shaft within a shaft shown in the center of this picture. The fuel control on the right has the same kind of protractor and linkage as the pitch control. The measurement between the center line of the concentric shaft and the center line of the fuel control shaft will determine the adjustable rod length which will also create a parallelogram. Power lever movement to the prop pitch control causes the fuel control to move the same amount.



#428

This typical curve illustrates the relationship of the cam in the prop pitch control to the cam in the fuel control during the power lever travel. This is the basic objective of power lever rigging. Across the bottom of the curve is the power lever angle in degrees representing travel from zero--which is reverse--to 100 degrees--which is maximum takeoff. The top solid line represents the prop pitch control cam effect on propeller angle as identified on the left side of the curve. The fuel control cam solid line is related to the fuel flow in pounds per hour on the right side of the curve. The values on this curve are typical only, since we are concerned more with the principle than the actual numbers.

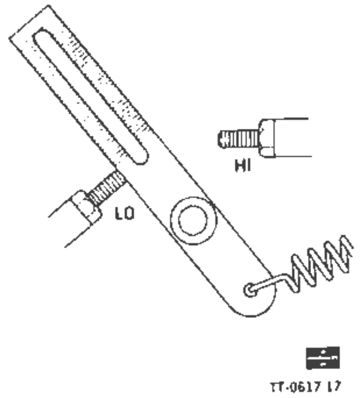
Notice the position of the prop pitch control cam when the power lever is at zero degrees on the protractor. Full reverse represents some negative blade angle, perhaps eight or ten degrees, on the propeller. As the power lever is advanced, we see the curve flatten out at the 40 degree flight idle position. The shaded area above the prop pitch control cam--when the power lever is at high degree position--represents a blade angle range that will be controlled by the propeller governor in the prop governing mode. You should recognize now that when the power lever is forward of flight idle, the propeller blade angle is not a function of the prop pitch control, but rather is controlled by the propeller governor. A key point in the relationship of these two cams is identified at flight idle.

Notice that both the cams are on a flat portion. When the power lever is at flight idle, the fuel flow will be a function of the flight idle fuel flow adjustment. The prop pitch control will be holding the propeller at the flight idle blade angle. This flight idle blade angle will be established by the adjustment of the beta tube when rigging the propeller to the engine and aircraft.

You will recall that in the event of engine flameout, the Pilot's Operating Manual would instruct him to move the power lever full forward. This is called the "Beta Followup System." You can see here on the prop pitch control cam curve that moving the power lever full forward would position the prop pitch control follower sleeve to maintain the highest possible blade angle. This would result in a minimum amount of drag on the dead engine in the event that the NTS system did not work.

SPEED LEVER RIGGING

USG STOPS ADJUSTED TO OBTAIN DESIRED ENGINE RPM IN BETA MODE BEFORE RIGGING

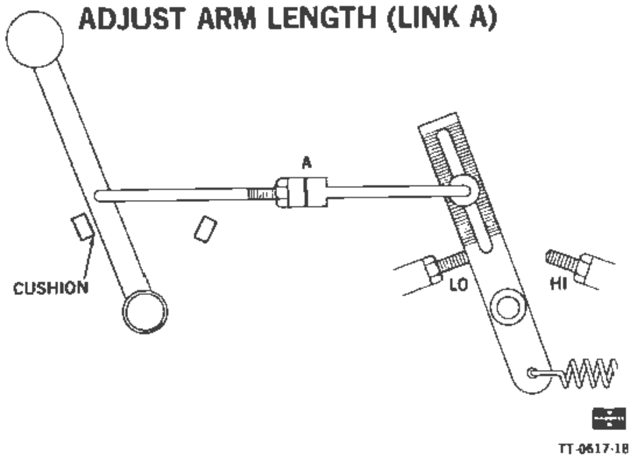


#429

The speed lever is responsible for positioning the underspeed governor and prop governor shafts relative to desired engine rpm in either beta, or prop governing modes. This picture illustrates the underspeed governor travel on the fuel control. There is a high stop and low stop adjustment to limit the travel of that lever arm. These stops will be adjusted prior to complete rigging so that the engine rpm can be established. The aircraft control is then rigged to contact these stops at their previous adjusted point. Notice that the underspeed governor arm is spring loaded against the low speed stop.

SPEED LEVER TO USG

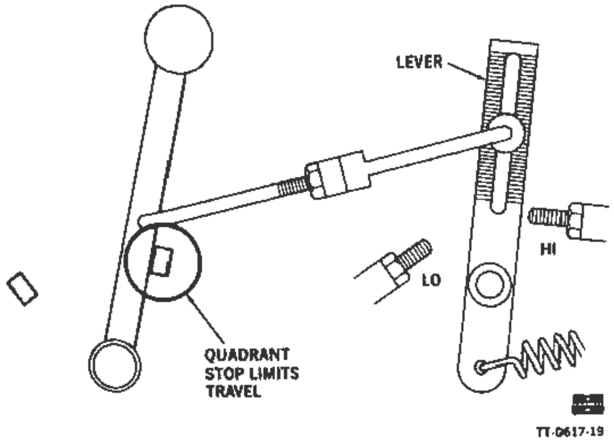
ADJUST ARM LENGTH (LINK A)



#430

When the underspeed governor stops have been set by running the engine, connection of the speed lever control in the cockpit to the lever arm on the underspeed governor will be made by adjusting the arm length "A." Contact must be provided at the stop while maintaining an adequate cushion at the quadrant.

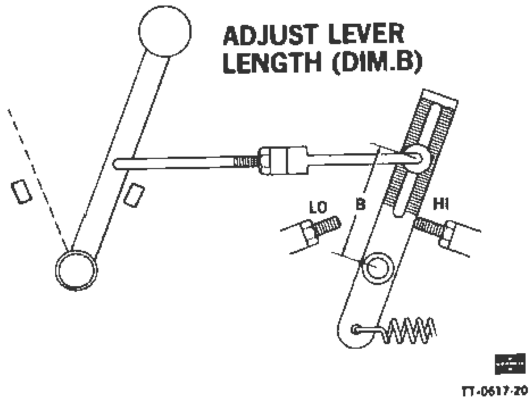
LEVER LENGTH PROBLEM



#431

It is obvious that setting the high speed stop to the 97 per cent rpm point would be of little consequence if you cannot reach that stop due to the speed lever reaching the end of its travel on the quadrant. This problem was discussed before in the power lever rigging portion and the same solution applies here.

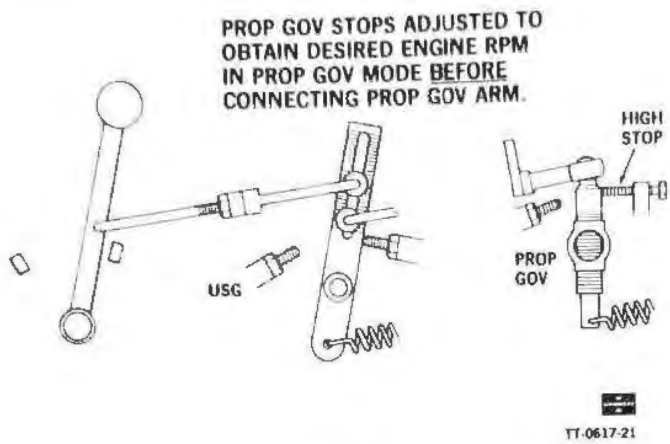
STOP TO STOP WITH CUSHION



#432

In order to establish the appropriate cushion at both ends of the speed lever travel in the quadrant, it may be necessary to adjust the dimension B to increase or decrease the length of the lever. This will increase or decrease the rotational arc of travel of the governor shaft so that contact of both the low and high stop can be made, while still maintaining the proper cushion on both ends of the speed lever travel.

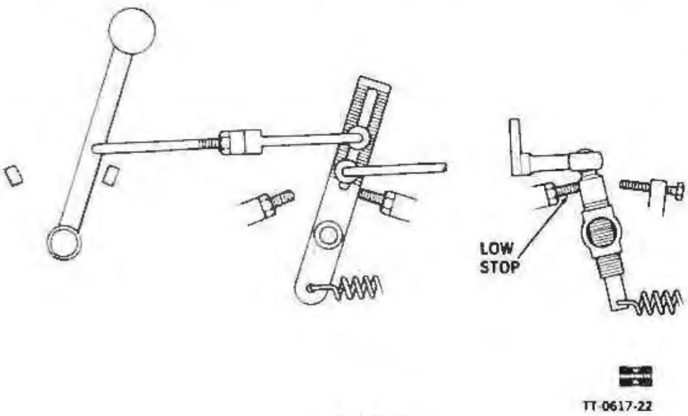
PROP GOV HIGH STOP ADJUSTMENT



#433

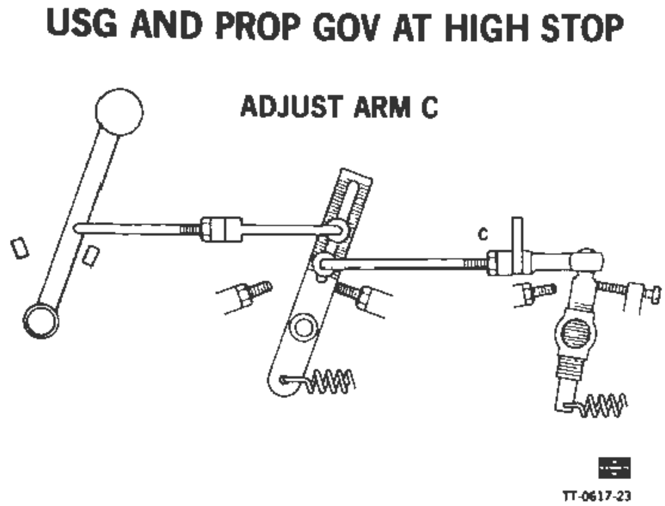
Adjusting the propeller governor high stop position must also be done by running the engine and making the adjustment to attain the desired 100 per cent rpm. This should be done with the linkage disconnected between the underspeed governor and the prop governor. The prop governor lever arm can be attached to the high stop by a heavy rubber band, or by a safety wire, during adjustment of the high stop.

PROP GOV LOW STOP ADJUSTMENT



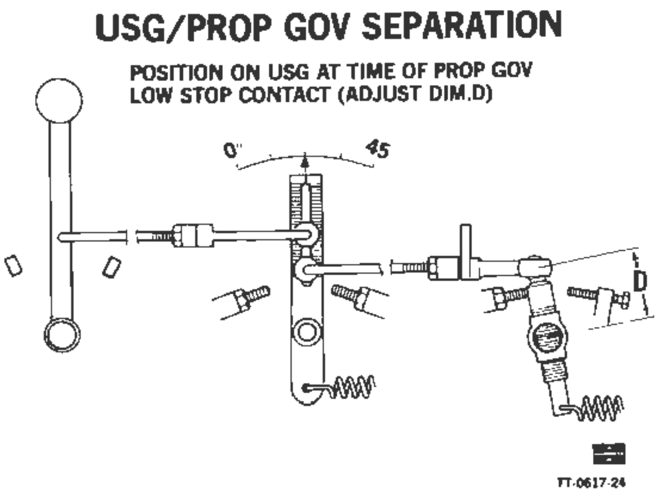
#434

The propeller governor lever can be attached to the low stop by the rubber band, or safety wire, and the engine will be run to attain the low stop adjustment per the manual. One should be careful in these adjustments not to exceed the torque and temperature limits established by the Pilot's Operating Handbook.



#435

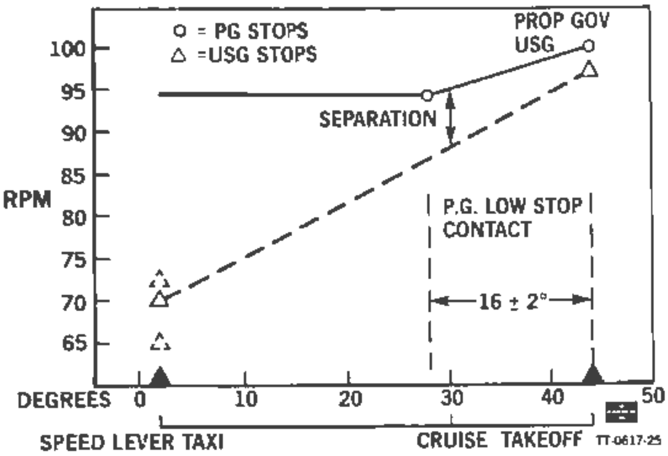
Now that the stops have been set on both the underspeed governor and prop governor to the desired values, arm "C" can be connected with both the governors against the high stop and the speed lever, maintaining the appropriate amount of cushion in the high rpm position.



#436

Typical rotation of the prop governor shaft will be limited by the low and high stop setting to approximately 10 to 12 degrees travel. The underspeed governor traveling from low stop to high stop will travel through an arc of approximately 40 to 45 degrees. It is evident that the linkage must be separable, otherwise, the total travel of the two would be limited by the minimum dimension represented by the prop governor low and high speed stop. The term "Governor Separation" can be identified mechanically as that point measured on a protractor on the underspeed governor shaft when the speed lever is retarded and the prop governor reaches the low stop. The rigging procedures in the manual will define the adjustment of dimension D so that the appropriate degree on the underspeed governor protractor will be indicated when contact is made with the prop governor low stop.

As the speed lever is retarded from the high rpm position, both governors will come off their high stops. When the prop governor contacts the low stop position, it stays there as the speed lever moves the underspeed governor to contact its low stop position.

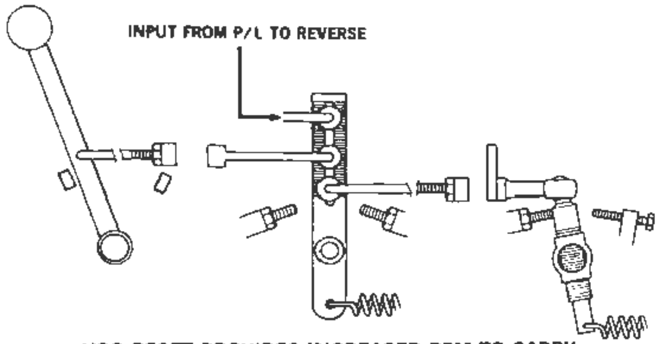


#437

This curve illustrates what happens to the propeller and underspeed governors as the speed lever is moved throughout its range. On the bottom of this curve is the speed lever position, from taxi to takeoff. Assume for a moment that the speed lever is at the takeoff position. As you move vertically from that position, you see that the prop governor high stop was set at 100 per cent rpm and the underspeed governor high stop was set at 97 per cent rpm. As the speed lever is moved toward the cruise position, both governors would be recalibrated to lower values. When the prop governor low stop is reached, the governor stops at that point and maintains the calibration point of approximately 95 per cent. As the speed lever continues back, the underspeed governor will be recalibrated to the ground taxi position, represented here by one of the three different settings for the -10 Engine. It may be the 65, 70 or 73 per cent setting. It is critical in the power management operation of the 331 that at least two and one-half degrees separation be maintained between those governors at any speed lever position.

Examination of the curve will indicate the mechanical rigging of this separation so that as you reach the propeller governor low speed stop, the protractor on the underspeed governor should indicate 16 plus or minus two degrees less than it did when the speed lever was in the takeoff position. Later in this section, we will describe an operational check of the governor separation by running the engine.

USG RESET FUNCTION



USG RESET PROVIDES INCREASED RPM TO CARRY REVERSE LOAD WHEN SPEED LEVER IS AT LOW RPM

#438

The underspeed governor reset system is a mechanical linkage that will protect the operator from demanding a full reverse load during the time when the speed lever is at taxi rpm. This could result in a bogdown of the engine speed by overloading and an excessive EGT condition. This could happen during taxi operation, where the pilot may pull the power levers back to full reverse under a condition where the speed levers were still at taxi. The underspeed governor reset system would automatically increase the underspeed governor's calibration as a result of a mechanical input from the power lever system.

As you can see in this linkage, the speed lever is at the taxi position. Input from the power lever attached to the lever arm would move the underspeed governor to increase the rpm and carry the load of full reverse without bogging down the engine. The mechanical rigging details of this power lever input will be described in the maintenance manual. Later on in this section, we will also describe an operational check to verify the underspeed governor reset function.

PROPELLER GOVERNOR RESET

- THE PROPELLER GOVERNOR IS RESET ABOVE 100% RPM BY POWER LEVER RIGGING TO PREVENT GOVERNOR INTERFERENCE WITH BETA CONTROL OF THE PROPELLER DURING LANDING
- HYDRAULIC RESET SYSTEM DESCRIBED IN PROPELLER CONTROL SECTION
- MECHANICAL RIGGING CONSIDERATIONS COVERED IN ENGINE MAINTENANCE MANUAL

FI-0617-27

#439

Propeller governor reset is important during the landing touchdown. When the power lever is brought back of flight idle, a signal to the reset system will cause the propeller governor to be recalibrated above 100 per cent rpm. This is to make sure the prop governor senses an underspeed condition and gives up prop control so that the beta system can take control of the propeller without any interference from the prop governor.

You will recall, from the discussions in the Propeller Section, that the hydraulic reset function depends upon the movement of a valve in the prop pitch control. The power lever is brought back of flight idle and the valve drains the oil from the prop governor reset piston. Although the prop governor reset is a hydraulic operation, there are several minor mechanical rigging considerations that will be described in the engine maintenance manual procedures.

CHECKOUT ITEMS

- (MM SECTION - ADJUSTMENT/TEST)
- OVERSPEED GOVERNOR
- USG RESET
- PROP GOV STOPS
- USG STOPS
- USG/PG SEPARATION
- FLIGHT IDLE FLAT
- FLIGHT IDLE FUEL - INITIAL ADJUST
- MAX POWER FUEL - STATIC
- REVERSE POWER
- FLAME OUT
- REVERSE POWER SYMMETRY
- FUEL MANIFOLD PURGE
- INLET ANTI-ICE
- NTS GROUND CHECK
- NTS LOCKOUT
- TORQUE/TEMP LIMITER
- FLIGHT IDLE FUEL - FINAL ADJUST
- MAX POWER FUEL - FLIGHT
- NTS CALIBRATION - FLIGHT

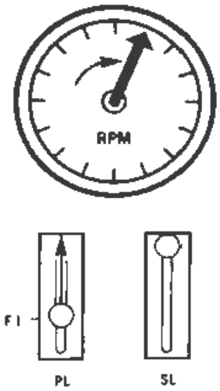
TT-0617-28

#440

This is a list of components and systems that can be operationally checked on the ground, or in flight. The engine maintenance manual section on Adjustment and Test supplies the detailed instructions needed to accomplish these tasks. In the next series of pictures, these checks will be reviewed one at a time, and the cockpit procedure involved in each check will be described. We will also consider those occasions when both engines must be matched. Also indicated will be what corrective action should be taken if the engine being tested does not meet the requirements.

OVERSPEED GOVERNOR

- PROP ON THE LOCKS
- ACTION-MOVE PL FORWARD
- OBSERVE-RPM HOLDING AT 103-105 AS PL ADVANCED
- CORRECTION-ADJUST OSG PER MM



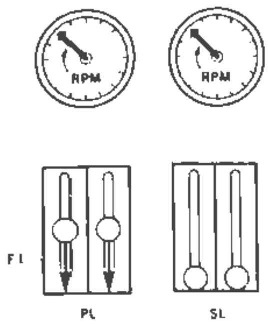
TT-0617-29

#441

In order to check the overspeed governor by running the engine, it will be necessary to keep the propeller on the locks. As long as the prop is on the locks, the propeller governor cannot control or change the blade angle. With the speed lever set at high rpm, the operator will move the power lever slowly forward towards the maximum travel position. During this travel, he should observe the tachometer and see that the rpm stops increasing within the range of 103 to 105 per cent as the power lever is advanced. This will indicate the calibration of the overspeed governor.

If the setting appears to be outside of these tolerances, the power lever should be retarded to avoid exceeding the maximum permissible speed dictated by the table of limit numbers in the Pilot's Operating Manual. Correction would involve adjusting the overspeed governor per the instructions in the maintenance manual.

UNDERSPEED GOVERNOR RESET



- PURPOSE-PROVIDE RPM FOR REVERSE LOAD WHEN SL AT TAXI
- ACTION-PL TO FULL REVERSE
- OBSERVE-RPM INCREASE TO SAME RPM ON BOTH ENGINES
- CORRECTION-ADJUST USG LINKAGE PER MM

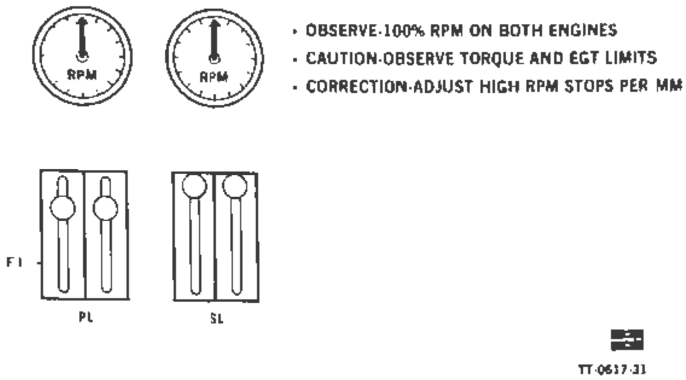
TT 0617 30

#442

The purpose of the underspeed governor reset is to provide the rpm for reverse load when the speed lever has been left at taxi. This is to prevent bogdown of the engine with the resulting high EGT. With the power levers initially set forward of flight idle, and the speed levers at the taxi position, the action required will be to pull both power levers to full reverse. You should observe the rpm increasing to the same rpm on both engines. This would result in a symmetrical reverse thrust. The correction to any malfunction indicated here would be to adjust the underspeed governor linkage per the maintenance manual.

There is a caution to observe. Check your Pilot's Operating Handbook for any limitations that may exist on accomplishing this test on your aircraft with both engines at the same time. The flight manual may restrict you to one engine at a time to avoid putting the aircraft back on the tail skid. It may be necessary to record the rpm as you check one engine at a time, so you can compare those readings when you are finished.

PROP GOVERNOR HIGH STOP

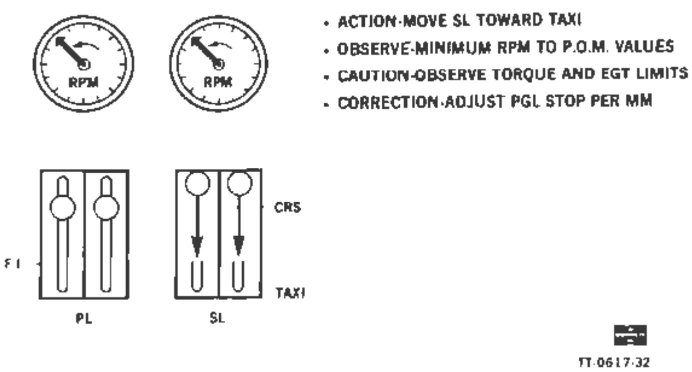


#443

In checking the high stop setting on the prop governor, it is recommended that both engines be checked at the same time. You are looking for precise tolerances on the tachometer. Should one of the tachometer indicating systems have an unacceptable error, it would be easily identified by audibly synchronizing your engines.

For checking the propeller governor high stops, have the speed levers full forward in the takeoff position and the power levers taken above flight idle far enough to be on the prop governor. Be careful that you do not exceed torque or temperature limits per the Pilot's Operating Manual. If the rpm is out of tolerance, the propeller governor high stop should be adjusted per the instructions of the maintenance manual.

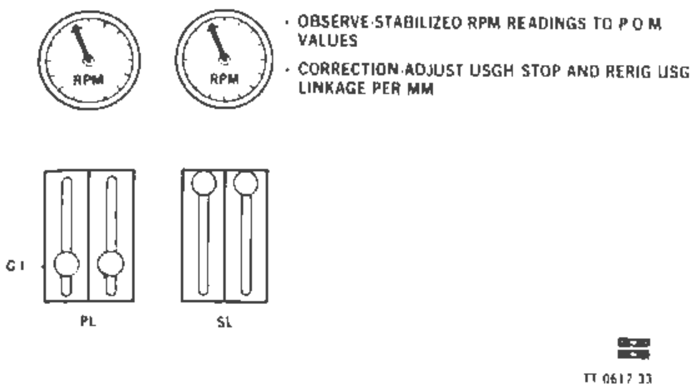
PROP GOVERNOR LOW STOP



#444

The prop governor low stop can be checked on both engines at the same time, for convenience. However, the accuracy of the low stop setting is not as critical as the high stop setting, so the engines can be checked at one time. The power lever should be in the prop governing mode of operation between flight idle and takeoff power. Be careful that you do not exceed torque and temperature limits. The speed lever should be brought back slowly and smoothly from the takeoff position through the cruise position and on towards the taxi position. During the period when you are retarding the speed levers, the tachometers should be noted to stop at approximately 94 to 95 per cent. This is the setting of the prop governor low stop. If correction is needed, adjust the low stop per the maintenance manual instructions.

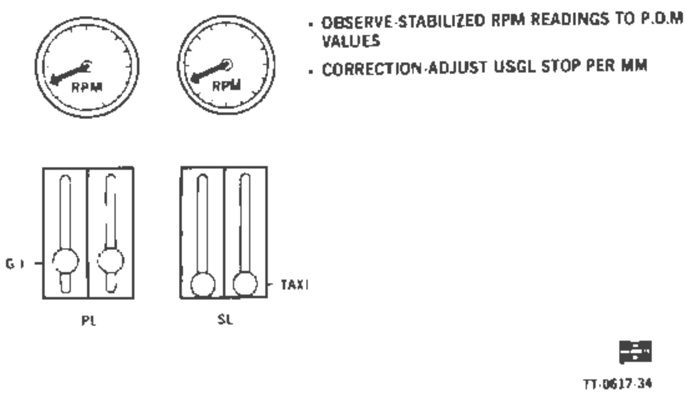
USG HIGH RPM STOP



#445

In order to check the adjustment of the underspeed governor high speed stops, the power lever should be placed at, or slightly aft, of ground idle to maintain a minimum blade angle. The speed levers should both be moved to the takeoff high rpm position. The tachometer readings will indicate the setting of the stops. If correction is needed, the underspeed governor high stop will be readjusted per the procedures of the maintenance manual. If an adjustment is made, it will be necessary to recheck the rigging of the underspeed governor linkage per the maintenance manual. If the high stop on the underspeed governor is readjusted, it may prevent the linkage from carrying the prop governor tightly against its high stop. The linkage may need a minor adjustment, depending upon the size of the underspeed governor high stop adjustment that was made.

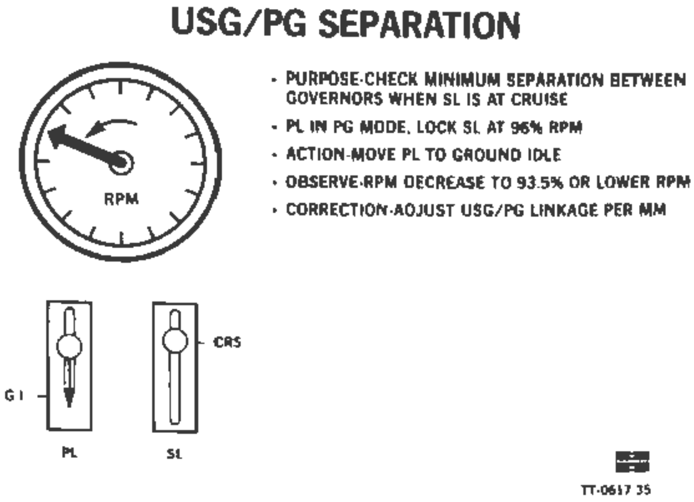
USG LOW RPM STOP



#446

In order to check the settings of the underspeed governor low stop, the power lever should be placed at, or slightly aft, of ground idle, maintaining a minimum blade angle. The speed lever should be pulled back to the taxi position. The resulting rpm indicates the setting of the underspeed governor low stops. If they need correction, they should be adjusted according to the procedures in the maintenance manual.

It should be recognized that the ground idle, or taxi speed, varies with different installations. The Pilot's Operating Manual will specify the rpm for your particular installation.

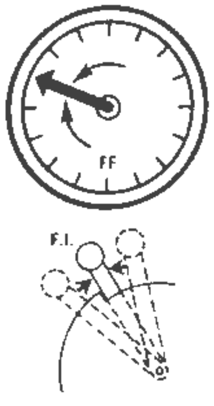


#447

In the discussion on the mechanical rigging, the separation necessary between the underspeed governor and prop governor was described. In this operational check, you can verify that there is a minimum separation maintained between the governors, particularly when the speed lever is at the cruise position. Separation must be maintained in order to prevent governor interference.

The procedure calls for placing the power lever in the prop governing mode position. Be sure you observe the maximum torque and temperature limits. With the speed lever slowly moved from the takeoff position back to 96 per cent rpm on the tachometer, the speed lever should be locked with the quadrant friction lock. The power lever should then be moved back to ground idle, or slightly in back of it. This means engine rpm will drop below the prop governor down to the speed controlled by the underspeed governor. Observe the tachometer and see that the rpm decreases to 93 and one-half per cent, or less. The difference between the prop governor at 96 per cent and the underspeed governor at 93 and one-half per cent represents a minimum of two and one-half per cent separation. It can be more, but should not be less than two and one-half per cent. If a correction is needed, it would be necessary to adjust the underspeed and prop governor linkage per the maintenance manual.

FLIGHT IDLE FLAT



- PURPOSE-CHECK RIGGING REPEATABILITY TO FLIGHT IDLE FLAT ON FCU CAM
- CONTROLS-SL AT TAXI
  PL AT GROUND IDLE
- ACTION
  1. PL TO FLIGHT IDLE AND RECORD FUEL FLOW
  2. PL TO POWER RANGE AND RETURN QUICKLY TO F.I. DETENT
- OBSERVE-FUEL FLOW RETURNS TO VALUE PREVIOUSLY RECORDED
- CORRECTION-CHECK A/C PL LINKAGE RIGGING PER A/C MM

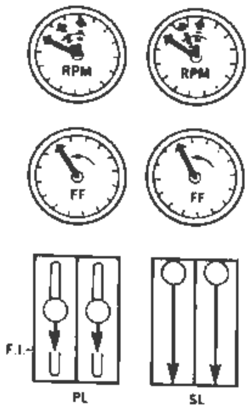
FT-0617 36

#448

The purpose of the flight idle flat check is to make sure that hysteresis in the control system will not prevent repeatability in the position of the flight idle flat in the fuel control cam.

To accomplish this check, start with the speed lever at taxi position, and the power lever at ground idle. The first action will be to move the power lever slowly to flight idle and record the fuel flow that is maintained at flight idle. Then move the power lever forward of flight idle into the power range and return it quickly to the flight idle detent. This simulates the action the pilot would make during landing. You should observe that the fuel flow returns to the value previously recorded. This check will assure the repeatability of the fuel control cam at the flight idle position whenever the power lever is at the flight idle detent on the quadrant. If correction is needed, the aircraft power lever linkage rigging should be checked per the aircraft maintenance manual.

INITIAL F.I. FUEL FLOW ADJUST



- PURPOSE-F.I. FUEL ADJUST AFTER FCU OR ENGINE CHANGE
- CONTROLS-PROP ON LOCKS SL HIGH RPM PL FORWARD OF F.I.
- ACTION-
  1. PL BACK TO F.I. AND OBSERVE RPM AND FUEL FLOW TO A/C MM VALUES
  2. SL TO TAXI AND OBSERVE RPM MINIMUM/MM
- CORRECTION-MATCH ENGINES RPM WITH F.I. FUEL ADJUST PER MM

  RECHECK MAX FUEL FLOW

TT-0617-37

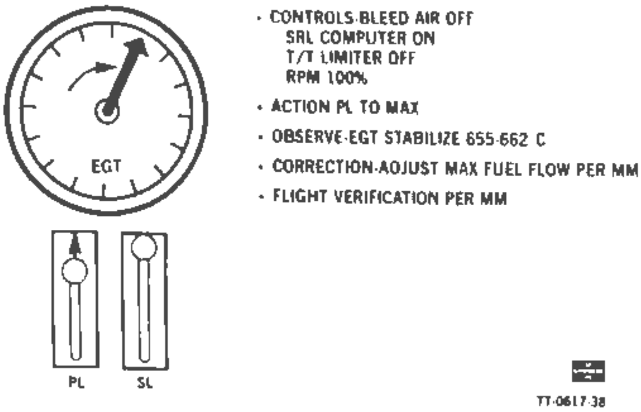
#449

The final adjustment of flight idle fuel flow must be accomplished in conjunction with flight test. However, if the mechanic has just replaced the fuel control, or possibly changed an engine, it will be necessary to establish an initial adjustment that will allow safe conditions for flight test.

During this adjustment, the propeller should be on the locks, thus, with load being constant, rpm will be a direct result of fuel flow. With the speed levers at high rpm or takeoff position, the power levers should be placed forward of flight idle. The actions involve several steps. First, the power lever should be brought back to flight idle and the rpm and fuel flow to the aircraft manual values observed. Secondly, the speed lever should be moved from takeoff back to taxi position and the rpm minimum, according to the maintenance manual, should be observed. If correction needs to be taken to match the engine's rpm, the flight idle fuel flow should be adjusted per the engine manual. Any time the flight idle fuel flow is adjusted, you should then recheck the maximum fuel flow adjustment, since it is affected by the flight idle adjustment.

It is important in this initial flight idle fuel flow adjustment that both engines be running at the same rpm as a result of flight idle fuel flow. This will ensure a symmetrical thrust condition at flight idle during the pilot's initial flight test.

MAX POWER FUEL FLOW—STATIC
(MAX EGT POSSIBLE WITHOUT EXCEEDING HP LIMIT)



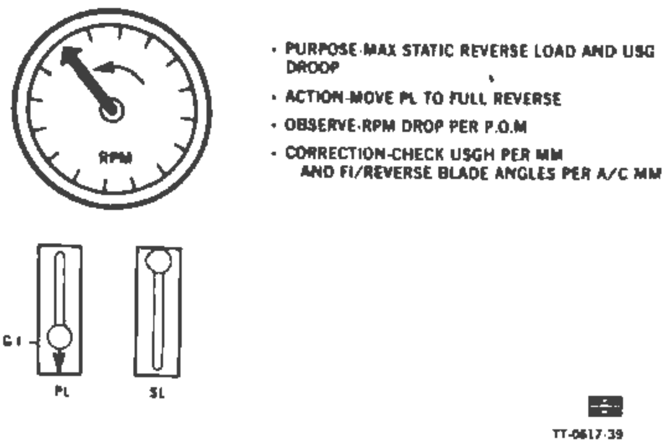
#450

Adjusting the maximum power fuel flow under static conditions on the ground requires that the ambient conditions allow a maximum EGT to be attainable without exceeding the torque limit. This will not be the case on most occasions with the -10 Engine. The -10 Engine, in most installations, will be flat rated so that the ambient temperature will have to be very high to cause you to reach the EGT limit before exceeding the torque limit.

We are assuming here that an ambient condition exists in which the operator can attain a maximum EGT without exceeding torque limit. In this case, you would proceed as follows. The bleed air system would be turned "OFF." The single red line computer should be turned "ON." The torque temperature limiter system should be "OFF." The engine should be running at 100 per cent with the speed lever in the takeoff position. The power lever will be cautiously advanced to the maximum stop position on the quadrant.

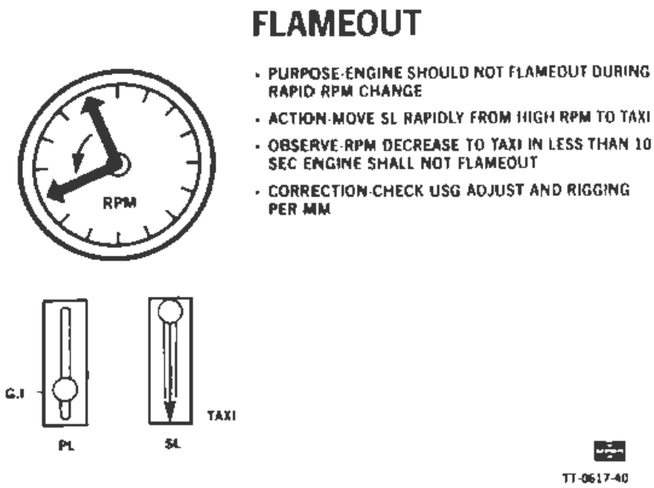
Observe the EGT gage as you advance the power lever and note that the temperature stabilizes between 655 to 662 degrees Celsius. The normal single red line limit is 650 degrees. This exceeding of the temperature of 5 to 12 degrees represents the overfueling capability just slightly above the normal limit to ensure adequate fuel under all ambient conditions. If correction is needed, it should be made by adjusting the maximum fuel flow adjustment on the fuel control per the maintenance manual. It is also recommended that the adjustment be verified by a flight test as described in the maintenance manual.

REVERSE POWER



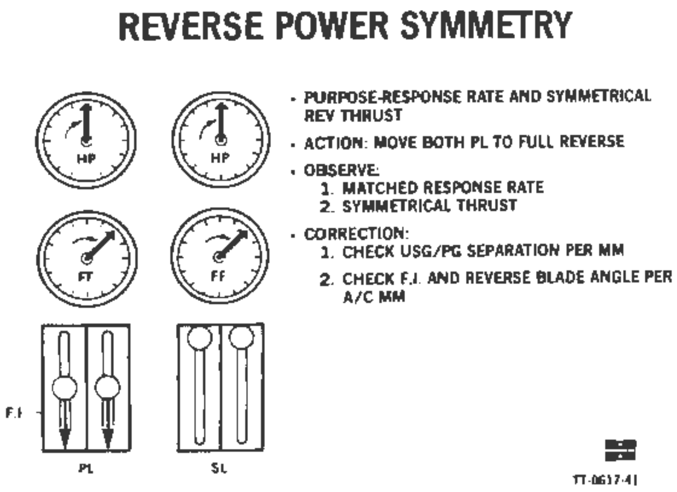
#451

This check will verify full reverse thrust as indicated by the percent in rpm droop of the underspeed governor as a result of carrying that load. With the speed lever in the high position, the power lever should be moved to full reverse. As the propeller goes into full reverse, it tends to load the engine down. The underspeed governor will sense this reduction in speed and increase the fuel supply to attempt to carry that load. The rpm will drop to some per cent that will be within the limits of the Pilot's Operating Manual. Typically, the rpm should droop no lower than about 94 and one-half per cent. It is obvious that if the aircraft was moving forward on a high speed landing, the same degree of blade angle in reverse would represent a greater load, and might possibly droop as low as 93 and one-half per cent. If correction is needed, the underspeed governor high stop should be checked per the maintenance manual and the flight idle and reverse blade angles should be checked per the aircraft manual.



#452

This flameout operational check will verify that the engine will not flame out during rapid action of the speed lever. With the power lever set at ground idle, the speed lever should be moved rapidly from high rpm to taxi within less than a second. You should observe the rpm decrease to the taxi rpm in less than 10 seconds and, of course, the engine should not flame out. This check may be repeated several times. If a correction is needed, you should check the underspeed governor adjustments and the rigging per the maintenance manual.

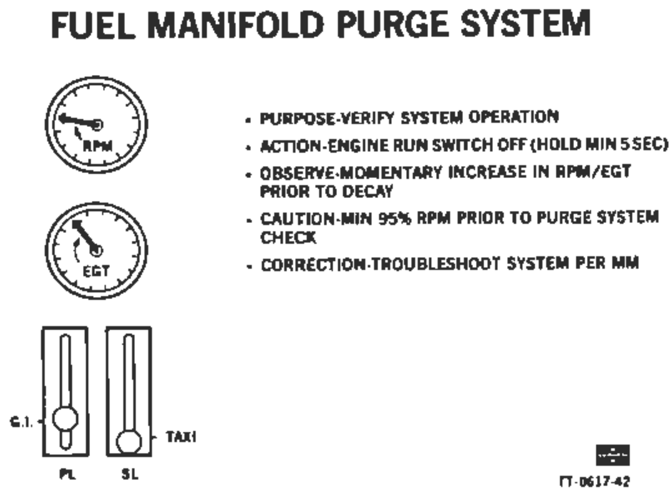


#453

The purpose of this check is twofold. We are interested in the response rate of the engine and propeller to the full reverse position and, in producing identical thrust from both propellers when in full reverse. Here again, the mechanic should check the Pilot's Operating Manual. If this check is attempted on some aircraft, you may put the tail on the ground. If your aircraft is limited, it will be necessary for you to check one engine at a time and note the readings for comparison.

Begin with the speed levers at high rpm and the power levers slightly forward of flight idle. The power levers should be moved smoothly and rapidly to the full reverse position. The first action that should be noted is that the response rate is matched between the engines.

By noting the torquemeters and the fuel flow, as well as the feel and sound of the engines, you can see that both of them respond at the same rate. This is important because if one engine were slower to respond than the other, this would create a yaw condition. Secondly, note the symmetrical thrust that is produced when both props are in full reverse. It is also obvious that if one was producing greater thrust than the other, it would tend to yaw the aircraft and pull it off the runway. If correction is needed because the response rate is not matched, check the underspeed governor and prop governor separation per the procedure previously discussed. If the thrust is not symmetrical at reverse, you should check the flight idle and reverse blade angles per the aircraft manual.

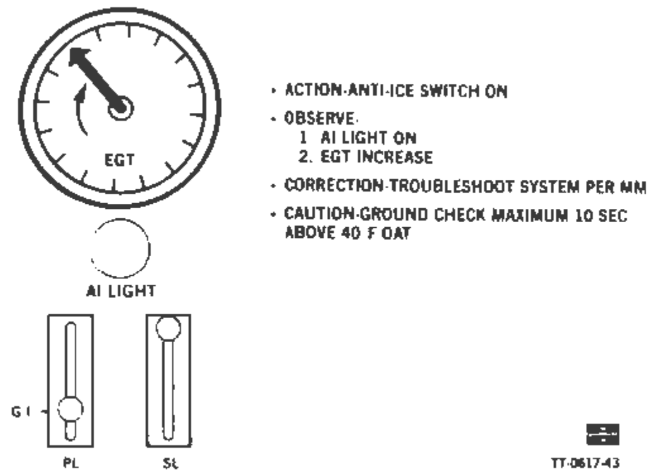


#454

You will recall that the fuel manifold purge system pushes the fuel from the manifolds into the combustion zone and burns it during shutdown. This is a requirement of Environmental Protection Agency regulations. The stop switch should be held in the "OFF" position for at least five seconds, or until the engine rpm has dropped below 50 per cent. This is to ensure total discharge of the accumulator to completely purge the systems. As that fuel is injected into the combustion zone, you should note a momentary increase in either rpm, EGT, or both, prior to decay. The engine should have been operated at high speed prior to shutdown to make sure the accumulator is fully charged.

If correction is needed, the fuel manifold purge system should be investigated per the troubleshooting procedures in the maintenance manual.

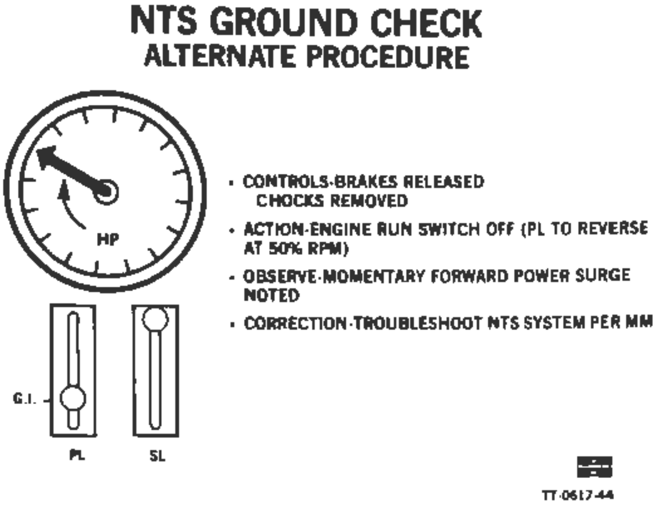
INLET ANTI-ICE SYSTEM



#455

The inlet anti-icing system can be operationally checked on the ground. As previously discussed, the bleeding of air from the compressor discharge represents a loss of power to the engine. This will be reflected by an increase in EGT. With the power lever at ground idle and the speed lever at takeoff rpm, the mechanic should turn the anti-ice switch on. He will observe two things. First, the indicator light for the anti-ice system in the cockpit should come on. At the same time, there should be a slight increase in the EGT. This indicates that the valve is opening and bleeding air into the anti-ice system. If a correction is needed, the system should be investigated per the troubleshooting procedures in the maintenance manual.

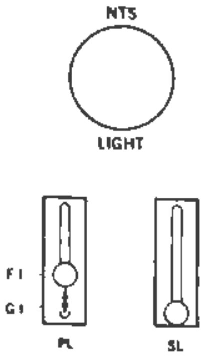
Pilot's Operating Manuals will caution against the use of this ground check exceeding the maximum of 10 seconds when the ambient air temperature is above 40 degrees Fahrenheit.



#456

The Pilot's Operating Manual will describe the procedure for checking out the NTS system operation during the ground check by accomplishing certain procedures during an engine start. The engine maintenance manual describes an alternate procedure that will be discussed here. The alternate procedure involves running the engine with the power lever in the ground idle position, the speed lever at high rpm and the prop off the locks. There is no thrust produced since the prop is at a flat blade angle. The brakes should be released and the chocks in front of the wheels should be removed. When the mechanic turns the engine run switch off, the fuel shutoff valve closes and the fire goes out in the engine. Since the propeller is still turning at high rpm, an instant negative torque condition is created. The NTS system activates the feather valve, dumping the oil from the propeller, and the propeller blades start toward the feather position. The positive blade angle results in forward thrust and a momentary forward surge of the aircraft will be noted. This surge verifies that the NTS system did take the necessary corrective action. The power lever can then be returned to the reverse position at approximately 50 per cent rpm, to put the prop back on the locks as a normal shutdown procedure. If correction is necessary, the NTS system should be investigated per the troubleshooting procedures in the maintenance manual.

NTS LOCKOUT



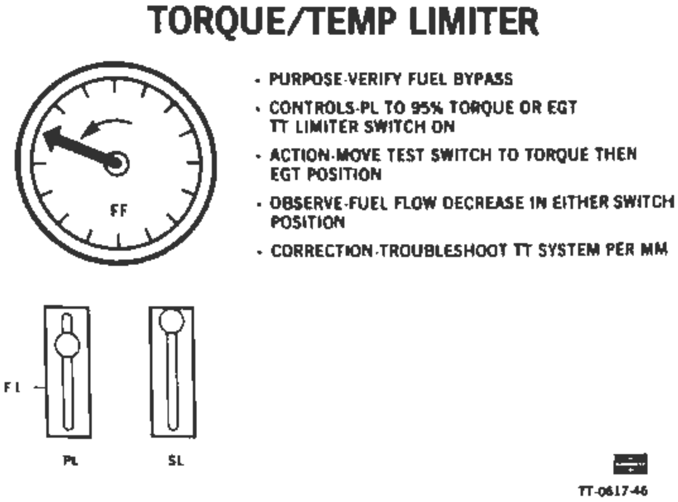
- PURPOSE-VERIFY PPC VALVE OPERATION. ENGINE NOT RUNNING
- CONTROLS-UNFEATHER PUMP ON NTS TEST SWITCH ON
- ACTION-ALTERNATE PL FROM F.I. TO G.I
- OBSERVE-NTS LIGHT OFF AT G.I NTS LIGHT ON AT F.I
- CORRECTION-PRESSURE TEST NTS LOCKOUT SYSTEM PER MM

TT-0617-45

#457

You will recall that the NTS system can be locked out during a landing procedure by the same system that resets the prop governor. This action is caused in both systems by a valve in the prop pitch control being opened when the power lever is brought back of flight idle. The purpose of this operational check is to verify the prop pitch control valve operation without running the engine.

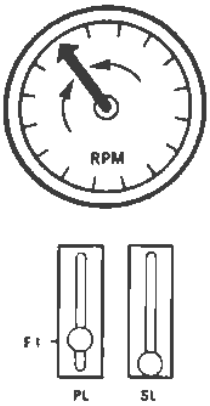
The initial position of the power lever will be at flight idle and the speed lever will be left at the taxi position. The unfeathering pump and NTS test switch should be turned "ON." The action of the unfeathering pump will be to pressurize the oil system and cause the NTS test light on the panel to come "ON." Moving the power lever from flight idle to ground idle position opens the valve in the prop pitch control. Observe that the NTS light goes "OFF." When the power lever is returned to flight idle, the NTS light should come "ON." It is this action between ground idle and flight idle that indicates that the valve in the prop pitch control is opening and closing as it should. If correction is necessary, there is a procedure in the maintenance manual describing how to pressure test the NTS lockout system with a gage.



#458

On those installations of the 331 where a torque/temperature limiter system is included, the limiter function is to bypass fuel back to the inlet side of the pump to limit that fuel as a function of either maximum torque or maximum temperature. The purpose of this test is to verify fuel bypass valve action when a simulated signal is put to the limiter that indicates that torque or temperature is being exceeded. The engine is actually run at some stable condition with the power lever in a prop governing mode of operation, and the speed lever at high rpm. (CAUTION: Do not exceed the torque or temperature limit.) The torque/temperature limiter system switch must be in the "ON" position. The action will be to move a test switch on the panel to the torque position and subsequently, to the temperature position, in each case, noting the decrease in fuel flow caused by the fuel bypass opening. In this way, the operation of the system can be verified without actually reaching an overtemperature or overtorque condition. If corrective action is needed, the torque/temperature limiter system should be investigated per the procedures of the maintenance manual.

F.I. FUEL FLOW—FINAL ADJUST



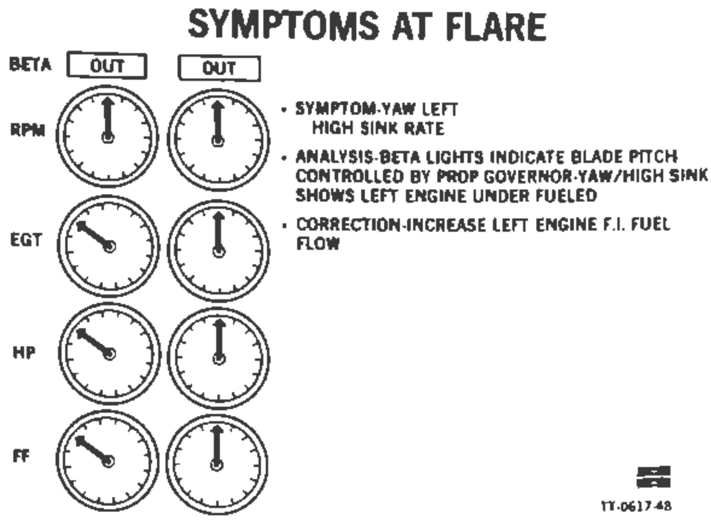
- FLIGHT TEST PER P.O.M. TO DETERMINE SYMMETRICAL THRUST AND DESIRED SINK RATE
- ADJUST F.I. FUEL FLOW ON GROUND CHECK TO ATTAIN DESIRED ACTION
- RECORD RESULTING GROUND CHECK F.I. RPM IN ENGINE LOG FOR REFERENCE

TT-0617-47

#459

We have previously described an initial flight idle fuel flow adjustment that can be accomplished when a fuel control or an engine change has occurred. This is to ensure a safe condition prior to flight test. The final flight idle fuel flow adjustment will be made following a flight test. The pilot will accomplish this flight test per the instructions in the Pilot's Operating Manual. In addition to the rate of descent, he is also looking for symmetrical thrust from both engines to eliminate any tendency for the aircraft to yaw under this condition. The mechanic will then make the necessary adjustments to the flight idle fuel flow to satisfy his flight test requirements. Once this has been done to the pilot's satisfaction, the mechanic should then run a ground check and determine what rpm the engine will run at with the flight idle fuel flow now being provided and record this in the engine records for future reference.

This illustration represents the position of the controls during the mechanic's ground check. Obviously, during flight, the pilot will put the controls in the position dictated by the Pilot's Operating Manual test procedures.



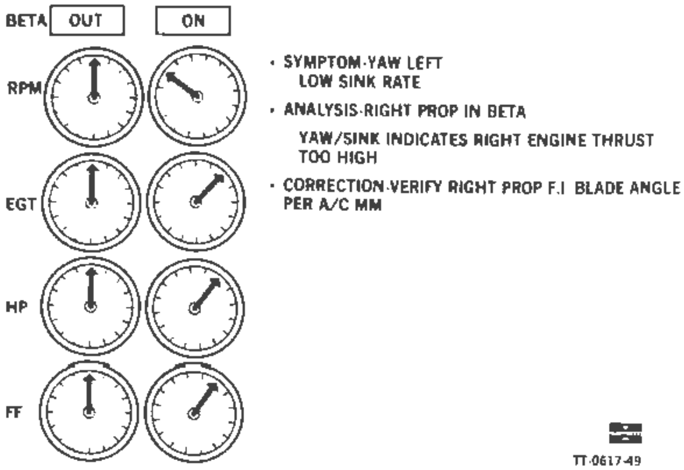
#460

A flight test to determine flight idle fuel flow adjustment is necessary since the mechanic cannot duplicate on the ground the conditions under which the engine, propeller, and aircraft, are operating at during a landing. This illustration is an example of the type of report that the pilot may bring back to the mechanic identifying what's happening to instrument indications, beta light indications and other symptoms, such as, the rate of descent or a yaw condition. The trained mechanic who can analyze these symptoms will be able to apply corrective action with a minimum amount of time and cost.

Consider this set of symptoms noted at the point of flare. The beta lights are both out. The rpm is the same at 100 per cent. The EGT, horsepower, and fuel flow on the left engine are lower than they are on the right. Additional symptoms indicate that when the pilot flared for landing, the aircraft tended to yaw to the left. Also, the sink rate was higher than it should be. Recognizing that thrust under these conditions is the function of blade angle and fuel flow, first of all consider what the blade angle may be doing. The fact that the beta lights are both out indicates that the blade angle is being controlled by the prop governor. The prop governor maintains the blade angle required to hold the rpm at 100 per cent. This problem cannot be the responsibility of improper blade angle. That leaves the fuel. When we consider that the aircraft yaws to the left, then it means either the left engine is underpowered or the right engine is overpowered.

Since the higher than normal sink rate indicates a total power less than desired, the obvious conclusion would be that the left engine is underfueled. Corrective action in this case would be to increase the left engine flight idle fuel flow.

SYMPTOMS AT FLARE



#461

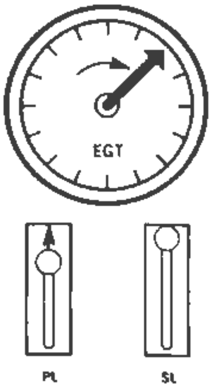
Another example of symptoms that the pilot may bring back to the mechanic is indicated here. Notice that the left engine beta light is "OUT" and the rpm, EGT, horsepower and fuel flow are apparently normal. The beta light for the right engine is "ON." The rpm is less and the EGT, horsepower and fuel flow are higher on the right engine than on the left. The additional symptoms indicate that at this point the aircraft was yawing to the left and the sink rate was lower than normal.

The fact that the right engine beta light is "ON" indicates that the prop blade angle is being controlled by the prop pitch control. The prop governor must obviously be sensing an underspeed condition allowing the beta light to come on indicating that the prop is being controlled by the beta system. The yaw condition indicates that either the right engine is overpowered, or the left is underpowered. The fact that sink rate is too low means the total power being produced is too much. This indicates that the right engine is producing too much thrust. You may question how the right engine could produce more thrust at a lower speed but, remember, the speed is a function of the load being carried and the power being produced.

Both power levers are at flight idle so the fuel flow is at a flight idle fuel flow adjustment level. If the blade angle were higher than normal, it would then tend to overload the engine. The fact that the rpm has been reduced indicates to the underspeed governor that more fuel is needed. The EGT and horsepower reflect the increased power being produced to carry the increased load. The corrective action in this case would be to verify the right propeller flight idle blade angle per the aircraft manual.

These two examples of analyzing the symptoms given by the pilot illustrate the point that communication between the pilot and mechanic is extremely important. It is important to encourage complete readings from the pilot as to what's happening to each of the instruments and to the beta lights, as well as, what the aircraft action is. You will have an opportunity in the workbook exercise later to look at additional examples of these symptoms.

MAX POWER FUEL FLOW—FLIGHT
(IF TORQUE LIMITED ON GROUND CHECK)



- CONTROLS-A/C 15,000 FT-150 KIAS
  ENGINE BLEED OFF
  SRL COMPUTER ON
  TT LIMITER OFF
- CAUTION-OBSERVE EGT TABLE OF LIMITS (°C AND TIME)
- ACTION-MOVE PL TO MAX
- OBSERVE-STABLE EGT 653-665°C
- CORRECTION-ADJUST MAX FUEL FLOW PER MM

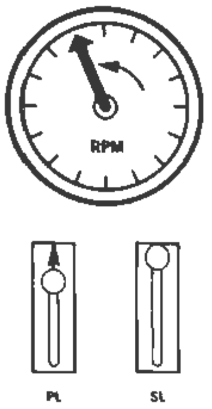
TT-0617-50

#462

The procedure for adjusting the maximum fuel flow is based upon obtaining maximum EGT. This circumstance will rarely occur on the ground run due to the flat rate condition of the -10 Engine. If you are torque limited on the ground check and cannot obtain maximum EGT, it will then be necessary to fly the airplane and check the maximum flow adjustment per the procedure.

During flight, it will be necessary to set up the controls as indicated. The speed lever will be at 100 per cent rpm. The aircraft will be at 15,000 feet with 150 knots Indicated Air Speed. The engine bleed air should be turned "OFF," the single red line computer turned "ON," and the torque temperature limiter switch turned "OFF." Be careful under these conditions of test that you do not exceed the EGT table of limit values both in temperature and time. Check the Pilot's Operating Manual for these limits. Move the power lever slowly to the maximum travel position and observe that the stable EGT is between 653 and 665 degrees Celsius. If in moving the power lever forward, it appears that the temperature is going to exceed those values, you should stop pushing the power lever, return to the ground and make an adjustment before rechecking. When properly adjusted, the power lever will be able to obtain the maximum travel to the forward position and the EGT should stabilize between these limits. The correction is to adjust the maximum fuel flow per the maintenance manual procedures.

NTS CALIBRATION — FLIGHT



- CONTROLS-A/C 5,000 FT 120-140 KIAS
- ACTION 1-ENG RUN SWITCH OFF PL TO MAX
- OBSERVE 1-RPM DECAY TO 40% WITHIN 30 SEC FEATHER AT 30% RPM
- CAUTION-DO NOT WINDMILL 20-26%
- ACTION 2-FUEL/IGN OFF UNFEATHER PUMP ON
- OBSERVE 2-WINDMILL TO 12-20% RPM WITHIN 30 SEC
- CORRECTION-NTS CALIBRATION PER MM

TT-0617-51

#463

Calibration of the torque sensor in the 331 Engine involves meeting two parameters. First, the NTS system should react at a low enough negative torque value to prevent the creation of an excessive drag in flight. Second, it must allow sufficient negative torque so that a proper air start may be accomplished by a windmilling propeller before tripping the NTS system.

With the speed lever at high rpm, and the power lever in the propeller governor range of operation, the aircraft should be at 5,000 feet above ground level and 120 to 140 knots Indicated Air Speed. The first action is to check the proper NTSing. With the engine run switch to the "OFF" position and the power lever moved to maximum, you would observe the tachometer and see that the rpm decays to at least 40 per cent rpm within 30 seconds. This decay of rpm is a function of the propeller going to the NTSing high blade angle condition. If the rpm is approaching the 30 per cent rpm point, then the emergency shutoff procedure should be followed to feather the propeller. Do not allow the engine to windmill in the 20 to 26 per cent critical frequency range.

The second check is to see that the proper windmilling cranking operation will be accomplished. Deactivate the fuel and ignition systems so that the engine will not light off and turn the unfeathering pump "ON." As the unfeathering pump drives the propeller out of the feathered position, the blade angle will cause a windmilling operation. The engine speed should windmill up to the 12 to 20 per cent rpm point within 30 seconds.

It will reach a point where the NTS system will prevent it from going any higher. The calibration of the torque sensor will not only protect you in the event of engine flameout, but will also permit a satisfactory windmilling operation for air starts. If correction is needed, the torque sensor calibration procedure of the maintenance manual should be followed. This normally will be accomplished by a service center which has the special tooling and test equipment that is required to calibrate the torque sensor. This is not normally a line maintenance function.

ENGINE INSTRUMENT MATCH

ASSUMPTION: ENGINES PRODUCING IDENTICAL POWER

RPM - TORQUE - EGT SHOULD MATCH WITHIN INSTRUMENT TOLERANCES BECAUSE :

- RPM - PROP GOVERNOR ADJUSTMENT
- TORQUE - RAW SIGNAL COMPENSATED
- EGT - EGT FACTORY COMPENSATED

SHOULD FUEL FLOWS MATCH - - ?

#464

We have now completed the ground and flight checkout procedures that are described in the maintenance manual. Pilots generally expect that the left and right engine instruments will match under a normal matched power lever condition. Is this a reasonable expectation?

Assume that both left and right engines have been completely checked out on the ground and in flight. Also assume that these engines are producing identical power. It is to be expected that the rpm, the torque and temperature should match under these conditions within the instrument tolerances. Obviously, no instrument is absolutely perfect, but these engine instruments should match within the relatively small tolerances permitted. As you look at each of them, you can see why. The rpm tachometer should certainly match, because the normal setting of 100 per cent rpm is a simple matter of a prop governor high stop adjustment.

You learned in the torque indicating system discussions that the raw signal is compensated so that it does match when the engines are producing matched power. The adjustment procedure for the torque transducer is described in the maintenance manual so that the instruments can accurately reflect the power being produced by the engine. Yes, the torquemeters should match.

You also learned in the EGT system discussion that the indicating system is factory compensated when the engines are in the test cells, so that when producing rated power, the same compensated EGT will be read. The compensation of these systems allows the engines to be operated to one number specified in the Pilot's Operating Manual. Now, for the next question. Should the fuel flow indicators match, since these are also one of the engine instruments?

SPECIFIC FUEL CONSUMPTION

SFC (LB/HP/HR) A RESULT OF EFFICIENCY

TYPICAL DATA SHEET INFORMATION:

	SPEC MAX	TYPICAL ACTUAL	HP
LEFT ENG	.558	.530	1,000
RIGHT ENG	.558	.550	1,000

#465

In the Theory of Operation section, you learned that the engine is nothing more than an energy converter, converting the fuel energy into useable power with the unconverted portions being lost as heat energy. Again, energy can be neither created nor destroyed, but can be converted from one form to another. It is obvious that no two mechanical devices would be exactly the same in their efficiencies. Acceptable differences in efficiencies are limited by meeting a specification.

When the engine is in a test cell, it must produce the rated horsepower without exceeding a specification in fuel flow or EGT.

Fuel flow is described as "Specific Fuel Consumption." This indicates how many pounds of fuel were consumed to produce each horsepower for one hour. As each engine is shipped, it includes the data sheet, commonly called "DSC." The data sheet will identify the information you see here. For example, the left engine has a specified maximum specific fuel consumption of .558 pounds per horsepower hour. It must produce its rated power without burning any more than that amount of fuel. The data sheet will reflect that under those test conditions, the engine actually produced 1,000 horsepower with an actual specific fuel consumption of .530, obviously, better than the specified maximum. The right engine produced 1,000 horsepower at a specific consumption of .550. Both engines met the specifications. However, it is obvious that the left engine is slightly more efficient than the right engine.

FUEL FLOW INDICATION

SPEC MAX – SFC (.558) × HP(1000) = 558 PPH

LEFT ENG – SFC (.530) × HP(1000) = 530 PPH

RIGHT ENG – SFC (.550) × HP(1000) = 550 PPH

- BOTH ENGINES BETTER THAN SPEC
- FUEL FLOW INDICATION NOT EXPECTED TO MATCH WHEN SFC IS DIFFERENT

#466

If you do a little simple arithmetic with these numbers, you can see that the specification maximum SFC of .558, multiplied by the 1,000 horsepower, would indicate 558 pounds per hour as the total fuel consumption, not to be exceeded in producing that 1,000 horsepower. You can see that the left engine at a specific fuel consumption of .530, produced 1,000 horsepower burning 530 pounds per hour, which is 28 pounds per hour less than the maximum permitted. The right engine produced 1,000 horsepower burning 550 pounds per hour. Both engines are better than the specifications, even though they are not the same. The fuel flow indication is not expected to match when the specific fuel consumption is different between the two engines.

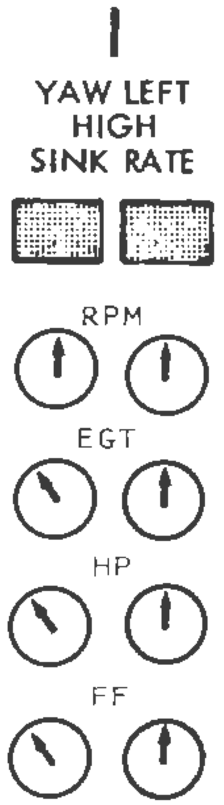
There is a practical application of the problem for the mechanic. If the specific fuel consumption happened to be identical on two engines originally installed on the aircraft, the pilot might be used to seeing matched fuel flow indicators. He might be a little upset when an engine change is accomplished and a new engine is put on with a different SFC. He may insist that both fuel flow meters should still match. He needs to look at the data sheet and be advised that his engines are alright in that they both meet the specifications, even though the efficiency of one engine is slightly different from that of the other.

WORKBOOK EXERCISE 10

SUBJECT:
SECTION 12 - OPERATIONAL CHECKOUT

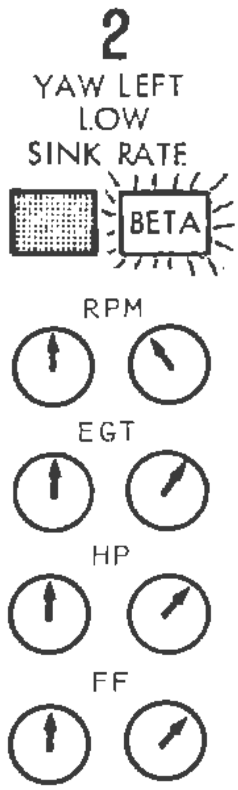
The pilot reported the following sink rate symptoms from flight tests at altitude of six different aircraft. Answer questions one through six by selecting the most appropriate corrective action from a through d below.

a. Increase left engine flight idle fuel flow.
b. Decrease flight idle fuel flow on both engines.
c. Check for correct flight idle blade angle on the right engine first, and then adjust fuel if necessary.
d. Decrease right engine flight idle fuel flow.



Corrective Action

1. ______________



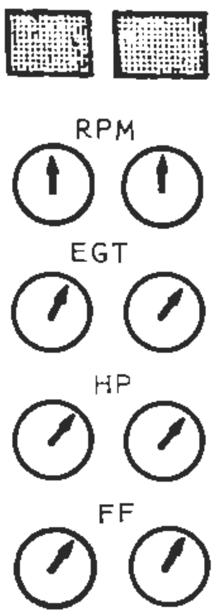
Corrective Action

2. ______________

WORKBOOK FXFRCISE 10

3

NO YAW
LOW
SINK RATE

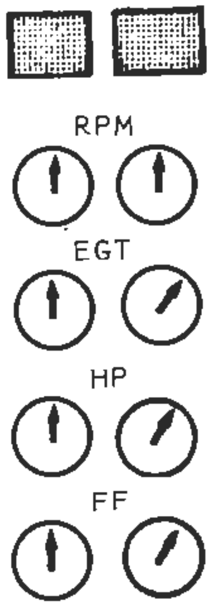


CORRECTIVE
ACTION

3. ________

4

YAW LEFT
LOW
SINK RATE

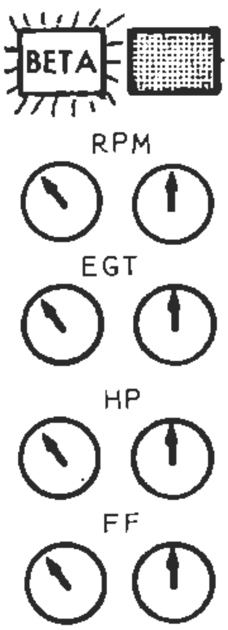


CORRECTIVE
ACTION

4. ________

5

YAW LEFT
HIGH
SINK RATE

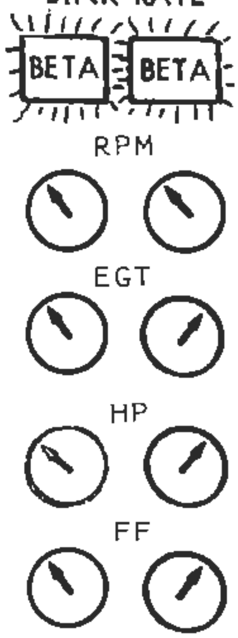


CORRECTIVE
ACTION

5. ________

6

YAW LEFT
HIGH
SINK RATE



CORRECTIVE
ACTION

6. ________

WORKBOOK EXERCISE 10

The repeatable load of full reverse can be very useful when analyzing cockpit instrument indications during troubleshooting procedures. The two examples shown in questions 7 and 8 indicate identical cockpit instrument indications during a maximum power check. A full reverse check provides additional information that indicates a different problem exists in each of the two examples.

For questions 7 and 8, analyze the indications at both maximum power and reverse and select the best answer from the following list.

a. Engine efficiency is low.
b. The engine is fuel limited.
c. The EGT indicating system is incorrectly reading higher than it should.
d. The torquemeter system does not accurately indicate the power being produced.

7. The pilot reported the horsepower to be less than normal when EGT limited at takeoff on a hot day. The mechanic verified this problem by the maximum power check indicated below. He then noted the results of a full reverse check.

	RPM	EGT	FUEL	HP
MAXIMUM POWER CHECK	NORMAL	LIMIT	LOW	LOW
REVERSE CHECK	NORMAL	HIGH	NORMAL	NORMAL

ANSWER ________________

8. On a different occasion and with a different aircraft, a pilot had the same complaint as identified in question 7. The mechanic's check of maximum power and reverse indicated:

	RPM	EGT	FUEL	HP
MAXIMUM POWER CHECK	NORMAL	LIMIT	LOW	LOW
REVERSE CHECK	LOW	HIGH	HIGH	NORMAL

ANSWER ________________

WORKBOOK EXERCISE 10

The pilot complains that "there is a power surge". His statement at this point could be interpreted to mean anything from a simple instrument problem to a serious propeller control malfunction. A more definitive description of symptoms can simplify troubleshooting procedures.

Answer questions 9 through 15 by selecting the most probable cause from the following:

a. Fuel system.
b. Prop system.
c. Indicator.
d. T/T limiter.

		ADDITIONAL SYMPTOMS	PROBABLE CAUSE
9.	 RPM ITT HP FF	NO CHANGE WHEN T/T LIMITER TURNED OFF	______
10.	 RPM ITT HP FF	NO CHANGE WHEN T/T LIMITER TURNED OFF	______
11.	 RPM ITT HP FF	NO CHANGE WHEN T/T LIMITER TURNED OFF	______
12.	 RPM ITT HP FF	HUNTING STOPS WHEN T/T LIMITER TURNED OFF	______
13.	 RPM ITT HP FF	NO CHANGE WHEN T/T LIMITER TURNED OFF	______
14.	 RPM ITT HP FF	NO CHANGE WHEN T/T LIMITER TURNED OFF	______
15.	 RPM ITT HP FF	NO CHANGE WHEN T/T LIMITER TURNED OFF	______

SECTION THIRTEEN:

TROUBLESHOOTING

HAVE WE MET PROGRAM OBJECTIVES?

THE STUDENT WILL BE ABLE TO PERFORM ROUTINE MAINTENANCE, TROUBLESHOOT EFFECTIVELY AND TAKE CORRECTIVE MAINTENANCE ACTIONS USING EXISTING INSTALLATION INSTRUMENTATION, TROUBLESHOOTING GUIDES AND THE APPROPRIATE MAINTENANCE MANUALS.

TT-0618 2

#469

Recalling the original objectives of this book, we set out to cover the subject of routine and corrective maintenance actions. In each of the sections previously covered, we discussed the routine items, as well as, a certain amount of troubleshooting or corrective maintenance actions. We will discuss additional troubleshooting assistance available to the mechanic in this section.

ROUTINE MAINTENANCE

- SERVICING
- INSPECTIONS

TT-0618 3

#470

General routine maintenance items described in the maintenance manual are included in either servicing or inspection procedures.

SERVICING

M/M 72-00-00 PAGE 301

- DEPRESERVATION
- PRESERVATION
- OIL SYSTEM
- ACCESSORY SHAFT LUBE
- WATER INGESTION
- FUEL ADDITIVES

TT-0018-4

#471

Section 72-00-00 in the Engine Maintenance Manual--beginning on page 301--covers the various servicing functions that are listed here: de-preservation and preservation procedures, oil system servicing, the greasing of the accessory shafts, corrective action to be taken in the event of water ingestion into the engine, and a description in the fuel portion relative to fuel additives.

INSPECTIONS

M/M 72-00-00 PAGE 601

- GENERAL VISUAL INSPECTIONS
- ENGINE CHECKS BASED ON PROP DAMAGE
- LIGHTNING STRIKES
- PERIODIC INSPECTIONS
  - PREFLIGHT
  - 100, 200, 400, 800, 1500 HOURS
  - TURBINE SECTION

TT-0018-5

#472

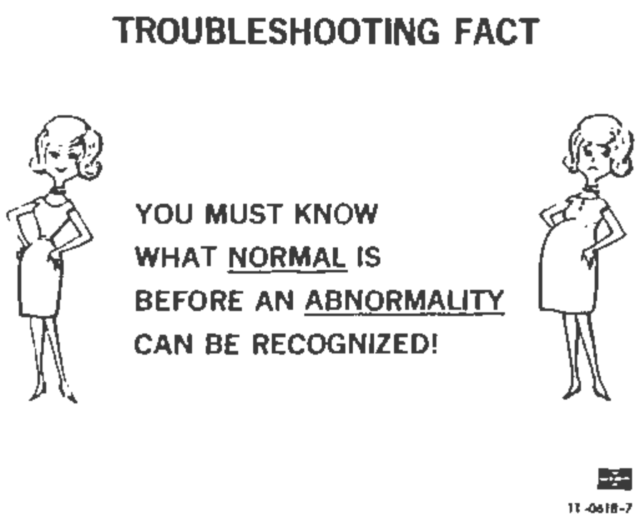
Recommended general inspection information is contained in the Engine Maintenance Manual in Section 72-00-00, beginning on page 601. Typically, subjects described will be: visual inspections, engine checks based on the extent of prop damage, lightning strikes, the periodic inspections such as Preflight, and the various 100, 200, 400, 800, and 1500 hour inspections. The turbine section inspections are also covered in this section. These various inspection procedures will also include the recommended corrective action to be taken.

CORRECTIVE MAINTENANCE

- **TROUBLESHOOTING**
  - RECOGNIZE SYMPTOMS
  - IDENTIFY PROBABLE CAUSE
- **CORRECTIVE ACTIONS**
  - UNIT REPLACEMENT (LRU)
  - CALIBRATION AND ADJUSTMENT

#473

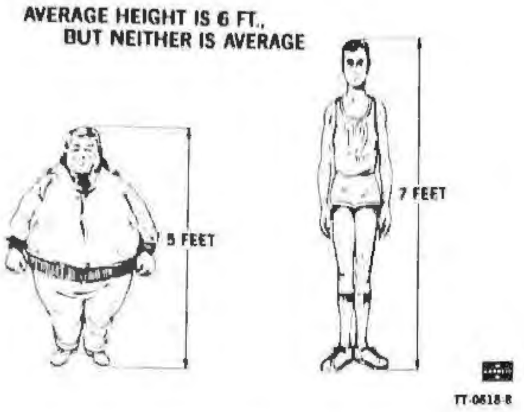
Corrective maintenance is the action taken once the cause has been identified. Obviously, the first requirement is to be able to recognize that a problem does exist. You must know what symptoms you have, and get a clean indication of those symptoms, in order to identify the probable cause. Once the cause has been determined, the corrective action will involve replacing, calibrating, or adjusting the unit if that's the course of action recommended by the manual.



#474

The ability of the professional mechanic to recognize a problem is dependent upon his background knowledge of what's normal. The point of this illustration is self-evident. If you know what your engine does before it has a problem, it will be much easier to recognize the abnormality when it does exist.

WHAT IS "NORMAL"?



#475

This cartoon illustrates the point that knowing what is normal is not necessarily that easy. The mechanic trying to build a backlog of information to assist in troubleshooting must be concerned with where and how he obtains these normal conditions.

NORMAL ENGINE DATA

MAY BE OBTAINED FROM:

- PUBLICATIONS
- INSTRUMENT MARKINGS
- HEALTHY ENGINES

#476

The mechanic has a number of sources available to determine the normality of his engine. Publications can help. For example, the Pilot's Operating Manual will identify the various degrees of blade angle, as well as, the correct engine rpm, torque and EGT under given conditions. The instrument markings can often assist in determining abnormalities. One of the best ways to know what is normal for your specific engine is to record those values when that engine is healthy.

GROUND OPERATIONAL CHECK

OPERATIONAL CHECK	SRL COMP	POS C/L	POS P/L	BETA LITE	IDEAL RPM %	RPM %	FUEL PPH	HP	EGT C	OIL P	OIL T
OVERSPEED GOVERNOR	ON	H	T O	—	104 ±1	—	PROP ON LOCKS NEVER EXCEEDED 105.5% 30 SECOND MAX				
FI FUEL CHECK	ON	H	FI	—	99 APX	—	—	PROP ON LOCKS FINAL ADJUST FLIGHT TEST			
REVERSE	ON	H	REV	—	MIN 94	—	—	—	—	—	—
T O POWER T/T LIMITER ON	ON	H	HP/EGT	—	100 ±5	—	—	—	—	—	—

RECORD IMPORTANT PARAMETERS
WHEN ENGINE IS WELL . . .

FOR DIAGNOSING LATER TROUBLE

TT0618-10

#477

One of the recommended ways for the mechanic to build a record of normal engine operation data is to create a simple form. The form illustrated here contains the type of information that is included in the Pilot's Operating Handbook and Maintenance Manuals.

The importance of this form is to get you to write the information down. For example, if you attempt to remember what the overspeed governor was set at on any given engine, it will be very difficult to make sure of that information at some later date. A simple form, with the various ground and flight operational checks previously covered, could be made up on your particular engine giving you a consistent recording format to follow. This can be very useful when diagnosing engine problems at a later date.

FLIGHT CHECK DATA

AIRCRAFT NO ______ LOCATION ________ DATE ______

GROSS WT ______ OAT _____ PRES ALT ________

PRESSURIZATION OFF

1. MAXIMUM CRUISE POWER CHECK

	LEFT	RIGHT
TORQUE		
TEMP		
FUEL FLOW		
RPM		

2. HIGH SPEED FLT IDLE DECEL CLEAN CONFIG

	LEFT	RIGHT
RPM		
FUEL FLOW		
YAW		
NTS		

3. APPROACH FLT IDLE CHECK LANDING CONFIG

	LEFT	RIGHT
RPM		
FUEL FLOW		
YAW		
RATE OF DESCENT	____ FPM	

4. STALL CHECK LANDING CONFIGURATION

	LEFT	RIGHT
RPM		
YAW		
BETA LT		
FUEL FLOW		

TT-0618-11

#478

This form is typical of what can be provided to the pilot for recording various data during flight that will be very useful to the mechanic. It takes very little time and effort on the part of the pilot to occasionally fill out a form such as this, yet it can be extremely useful in troubleshooting.

IDENTIFY PROBABLE CAUSE

72-00-00 PAGE 101

- INDEX CHARTS

  IDENTIFY PROBLEM INTO
  ENGINE OPERATING CATEGORY

- PROCEDURE CHARTS

  LIST OF SPECIFIC ACTIONS
  TO ISOLATE CAUSE

TT-0610-12

#479

Once the mechanic has recognized that there are symptoms and gets a clean indication of those symptoms, the next problem involved in troubleshooting is to identify the probable cause. The professional mechanic will use any assistance available to him in this activity. The Engine Maintenance Manual, in Section 72-00-00--starting at page 101--will provide considerable assistance in locating the probable cause.

The manual includes two types of charts in this section. The first is identified as an "Index Chart" that will help confine the problem to a given engine operating category. Once the appropriate category has been determined, the index chart will refer the mechanic to a specific "Procedure Chart," which will give him a list of recommended actions which can be taken in sequence to most quickly isolate the probable cause.

INDEX CHART CATEGORIES

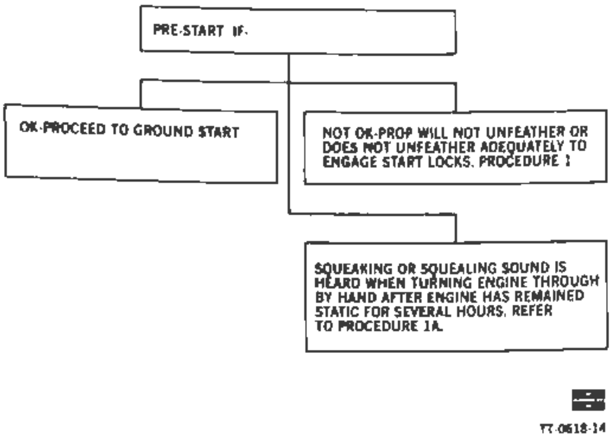
- PRESTART
- GROUND START
- AIR START
- RUN UP AND ENGINE CHECK
- CRUISE
- LANDING
- REVERSE THRUST
- MISCELLANEOUS
- SHUTDOWN
- TORQUE/TEMP LIMITING

TT-0614-12

#480

The troubleshooting index charts in the maintenance manual are broken down into the categories listed here. This list covers all conditions from prestarting through the various modes of operation. Armed with a written list of symptoms, you would approach the index charts looking for a set of circumstances that match the indications you have. You should be able to determine whether this set of symptoms was obtained during a prestart condition, during the ground start, or during any one of the other categories such as, runup and engine check, cruise conditions, landing conditions, reverse thrust conditions, and so forth. The index chart will refer you to the appropriate procedure chart.

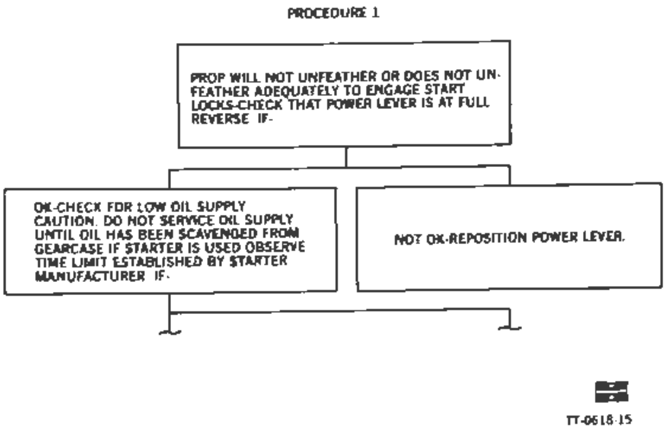
SAMPLE INDEX CHART



#481

This is a typical example of one of the index charts in the maintenance manual. The top block indicates the problem occurred during prestart and if you go down to the first block on the left, it says, "if OK, proceed to the ground start operation." This is obviously not OK, in your case, if you have a problem during the prestarting. You should refer to the first block on the right. "If not OK, the propeller will not unfeather or does not unfeather adequately to engage the start locks." If this matches your set of symptoms, then this chart refers you to Procedure One. Let's turn to Procedure One.

SAMPLE PROCEDURE CHART



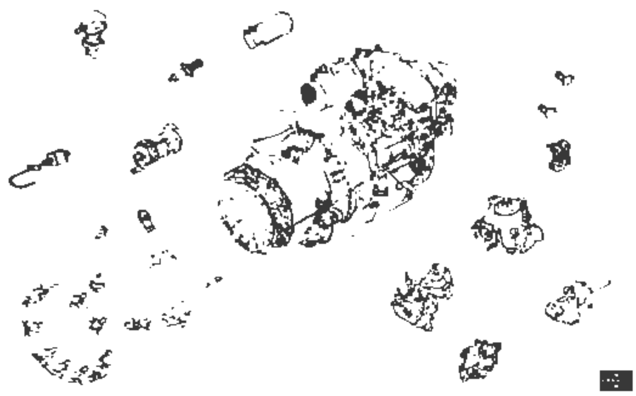
#482

This is part of Procedure One from the maintenance manual. Notice that the top block repeats the set of indications that the prop will not unfeather or does not unfeather adequately to engage the start locks. The first action it says to take is to check that the power lever is at full reverse. If the power lever is not where it should be, then obviously the correct action is to reposition the power lever so it is in full reverse. If the power lever was indeed in full reverse, the next item would be to go to the block on the left, and so on down.

This chart procedure leads you through a logical sequence, step-by-step, doing those things that are the easiest to check out first and ultimately helping you in locating the probable cause. Your manual includes approximately 100 pages of this type of assistance. It has been put together with much thought by Engineering, Field Service and Customer Service People.

The good troubleshooting mechanic will use all of the assistance he can get. You should locate and learn to use these charts.

CORRECTIVE ACTION
UNIT REPLACEMENT (LRU)



#483

Once the symptoms have been reduced to locating the probable cause, the mechanic then is concerned with what corrective action he takes. This may involve replacing a component. "LRU" stands for Line Replaceable Units. There are a number of components on the engine that fall into this category and may be replaced as a line maintenance function. This, of course, depends on your own capabilities and in the stock of these parts that you have available.

CORRECTIVE ACTIONS

CALIBRATION/ADJUSTMENT

TYPICAL TEST EQUIPMENT AVAILABLE:

- SRL/AUTO START COMPUTER TESTER
  DESCRIBED IN THE TEMPERATURE INDICATION SECTION
- FUEL MANIFOLD PNEUMATIC FLOW TESTER
  DESCRIBED IN THE FUEL SYSTEM SECTION
- STANDARD TEST GAGES

TT 0618 17

#484

The recommended corrective action does not always consist of replacing a part. It may be nothing more than a simple matter of adjustment, or recalibration, of a component. During the course of this book, we have described several pieces of test equipment that can help when calibrating or adjusting the various devices on the engine. The Single Red Line Auto Start Computer Tester was described in the Temperature Indication and Fuel System sections. This can be a very useful tool when dealing with those components. The Fuel Manifold Pneumatic Flow Tester was described in the Fuel System section. Much can also be done on this engine with just standard test gages found in most maintenance shops.

YOU ARE NOT ALONE . . .

HELP IS AVAILABLE THROUGH GARRETT WORLDWIDE SERVICE ORGANIZATION.

- AREA FACTORY REPS
- SERVICE AND REPAIR FACILITIES
- FACTORY CUSTOMER SERVICE

REFER TO SERVICE INFORMATION LETTERS SIL P331-22 AND 27 FOR ADDRESS INFORMATION

TT-0618-18R

#485

The professional mechanic will also take advantage of all the additional help available to him. Help is available throughout the Garrett world wide service organization. This consists of area factory representatives located in practically all of the countries of the world. This will also cover the service and repair facilities that are authorized and trained by Garrett. These facilities will not only have the test equipment and expertise, but they also maintain a supply of the necessary parts. Also, factory customer service people are available to answer questions and provide recommendations. They can be contacted either by telephone, or by telex, for quick action. The Service Information Letters P331-22 and -27 describe all of the area representatives, where they are located, and what their telephone numbers are. Also included are the repair facilities and the factory service people in Phoenix.

WHAT HAPPENS NOW?

YOUR REFERENCE MATERIAL, TEST EQUIPMENT, TRAINING AND MAINTENANCE KNOWLEDGE ENABLES YOU TO ACHIEVE THE EXCELLENT RELIABILITY AND PERFORMANCE CAPABILITIES OF YOUR TPE331 TURBOPROP ENGINE.

A TRUTH ABOUT TRAINING···

USE IT OR LOSE IT!

#486

The material and training that you have received will certainly assist you in achieving the reliability and performance capabilities of your 331 Engine. There is a truth about training. You must use it or lose it. It would be beneficial to put into practice the procedures and information that you have learned here as soon as possible.

TSG-103
REVISED
2-1-81

GLOSSARY

GLOSSARY

Absolute: The magnitude of a pressure or temperature above a perfect vacuum, or absolute zero. Absolute zero is theoretically equal to -273.18°C or -459.72°F.

Acceleration: A change in velocity per unit of time.

Acceleration Due to Gravity: The acceleration of a freely falling body due to the attraction of gravity, expressed as the rate of increase of velocity per unit of time (32.17 feet per second per second at sea level at 45 degrees latitude)

Air (Standard): Standard air is based on sea level atmospheric conditions of temperature at 15°C (59.9°F) and air pressure at 14.7 psi (29.92 inches of mercury). Corresponding standard air values for other altitudes are obtained from charts or altimeter readings.

Ambient Air: Air surrounding the outside of a unit or component.

Atmosphere (Standard): See Air (Standard)

Axial-Flow Compressor: One in which the air is compressed while flowing approximately parallel to the axis of rotation of the compressor.

Axial-Flow Turbine: One in which energy in flowing air is converted to shaft power while the air follows a path parallel to the turbine's axis of rotation.

Annular Combustor: Ring shaped combustor.

Atomizer: A device through which fuel is forced so that it enters the combustor as a fine spray.

Beta: Engine operational mode in which prop blade pitch is hydromechanically controlled from cockpit power lever. Used for ground operations.

Blade: A rotating fin used in a compressor as a means of compressing air, or in a turbine for extracting energy from the gases.

Blowout: Loss of flame during operation due to fuel-air mixture being too rich or too lean.

British Thermal Unit: Used for measuring heat and equals the quantity of heat required to raise the temperature of one pound of water from 62°F. to 63°F.

Burner, Can, Combustor, Flame Tube, Liner: The holed, sheet metal assembly which contains the flame.

Choked Flow: In an orifice, the condition where air moves through the constriction at the speed of sound and downstream pressures have no effect on flow.

Clearing the Engine (Motoring): Removing unburned fuel from the combustion chambers by rotating the engine with the starter. The airflow caused by the compressor will carry off dangerous accumulations of fuel vapors and vaporize the liquid fuel present.

Combustion Chamber: The section of the engine into which fuel is injected and burned, and which contains the flame tube or combustor.

Compression Ratio: Comparison of the pressure (or volume) of air discharged from a compressor to the pressure (or volume) of air entering it. See "Pressure Ratio".

Compressor: The section of the engine which acts like an air pump to increase the energy of the air received from the entrance duct and discharged into the turbine section.

Compressor, Centrifugal: One in which air is compressed while directed outward from its axis or center.

Compressor Surge: An operating region of violent pulsating airflow, usually outside the operating limits of the engine. A cause of compressor surge is compressor stall due to excessive restriction of airflow from the compressor. A compressor surge may result in flameout and, in severe cases, may cause physical damage.

vergent Duct: An air passage or channel of decreasing cross-sectional area. A gas flowing through such a duct is made to increase its velocity and decrease its pressure.

al Speed: The speed(s) at which a component produces maximum vibration.

Delta P (ΔP): Delta or Δ is the difference between two values, so ΔP is the amount of pressure change from one point to another.

Density: The ratio of the mass of a homogenous fluid to its volume, at a given temperature and pressure; also called mass density.

Density Altitude: The altitude that corresponds with the given air density (pressure and temperature) in the standard atmosphere.

De-Swirl: A turning-vane assembly used to straighten airflow.

Diffuser: A duct of increasing cross-sectional area which is designed to convert high speed gas flow into a low speed flow at an increased pressure.

Divergent Duct: An air passage or channel of increasing cross-sectional area. A gas flowing through such a duct is made to decrease its velocity and increase its pressure.

Droop: A decrease in speed, voltage, air pressure etc. which results when load is applied.

Duct: A passage or tube used for directing gases.

Dynamic Balance: A mass that will remain free of vibration while in motion is said to be dynamically balanced. It is a condition in which all forces exerted on various parts of the mass are balanced by equal opposing forces.

Efficiency: Ratio of power output to power input. Power input equals power output plus power wasted.

Energy: A body possesses energy when it is capable of doing work or overcoming resistance. Energy is "stored work" waiting to be used, and is expressed in foot pounds. There are two forms of energy: potential and kinetic. Potential, or latent, energy is the capacity of a body to perform work due to its position or chemical composition, or due to its tendency to return to an original shape after being deformed. Kinetic, or actual, energy is due to the motion of a body, and represents the ability of the body to interact with another body to produce a change in velocity or direction.

Exducer: An axial-flow type turbine wheel attached to the discharge end of a radial flow turbine wheel.

Exhaust Gas Temperature (EGT): The temperature of the exhaust gas at the discharge side of the turbines, usually a known amount less than turbine inlet temperature.

False Start: An unsuccessful or aborted engine start.

Fan: In turbofan engines, a fixed pitch enclosed propeller.

Flameout: An unintentional extinction of flame.

Fluid: Any substance having elementary particles that move easily with respect to each other, i.e. liquids (incompressible fluid) and gases (compressible fluid).

Force: Any action which tends to produce, retard, or modify motion.

Free Turbine: One which operates independent shafts for high pressure and low pressure rotors.

Fuel Control Unit: A device used to regulate fuel flow to the combustion chambers. It may respond to one or more of the following factors: power control lever setting, inlet air temperature and pressure, compressor rpm, combustion chamber pressure, and exhaust temperature.

Gas Turbine: An engine consisting of a compressor, burner or heat exchanger, and turbine, using a gaseous fluid as the working medium, producing either shaft horsepower or jet thrust, or both.

Guide Vanes: Stationary airfoil sections which direct the flow of air or gases from one major part of the engine to another.

Hertz (Hz): Frequency in cycles per second.

Horsepower: One horsepower is the amount of force needed to move 33,000 pounds through a distance of 1 foot in 1 minute (or 550 foot-pounds per second).

$$HP = K \times \text{torque (ft lbs)} \times \text{rpm}$$
$$HP = .0001904 \times \text{ft lbs} \times \text{rpm}$$

Hot Starts: An engine start, or attempted start, which results in the turbine temperature(s) exceeding the specified limits. It is caused by an excessive fuel-to-air ratio.

Igniter: A device, such as a spark plug, used to start the burning of the fuel/air mixture in a combustion chamber.

Impeller: The main rotor of a radial compressor which increases the velocity of the air which it pumps.

Inducer: A curved vane axial flow section at the inlet(s) of a radial impeller.

Induction System: The system that admits air to the engine, consisting of inlet ducts and an inlet plenum.

Interstage Turbine Temperature (ITT): Gas temperature measured at inlet of second stage turbine stator assembly (referred to as Station T 4.1).

Kinetic Energy: Energy due to motion.

Load Control Valve (LCV): Valve which monitors bleed loads thereby limiting turbine temperature.

Labyrinth Seal: A high speed seal which provides interlocking passages to discourage the flow of air, oil, etc., from one area to another.

Lightoff: Ignition of the fuel/air mixture in the combustion chamber.

Mach Number: The ratio of the velocity of a mass to the speed of sound under the same atmospheric conditions. A speed of Mach 1.0 means the speed of sound, regardless of temperature; a speed of Mach 0.7 means that the speed is 7/10 the speed of sound for that particular temperature; a speed of Mach 1.5 means that the speed is 1 1/2 times the speed of sound for that particular temperature; and so forth.

Mass: A measure of the quantity of matter contained in a body. The mass of a body equals the weight divided by the acceleration due to gravity. The standard units of mass are the pound (English), the gram (Metric), and the slug (Aeronautical Computation). $\text{Mass} = \frac{\text{weight (lbs)}}{32.17} = \text{slugs}$

Main Metering Valve (MMV): Valve within the fuel control whose position establishes fuel flow to the combustor atomizers. The MMV position is determined by inputs from underspeed governor, power lever position, P3 sensing, and T2 sensing.

Mass Flow: Airflow measured in slugs/seconds.

Micron: A unit of length equal to one thousandth of a millimeter or 1/25,000 of an inch.

Motoring: See "Clearing the Engine".

Newton's Law: Inertia - a body continues in a state of rest or of uniform motion in a straight line unless acted upon by an external force.

Negative Torque Sensing System (NTS): Negative torque is a condition wherein propeller torque drives the engine; the NTS detects this and drives the propeller automatically to high pitch to reduce drag on the aircraft.

Nozzle, Fuel: A spray device which directs atomized fuel into a combustion chamber.

Nozzle, Turbine: A convergent duct through which hot gases are directed to the turbine blades.

Ohm: A unit of electrical resistance.

Orifice: A calibrated restriction; acts in a fluidic system somewhat like a resistor in an electrical system.

Overspeed: Engine speed which exceeds the selected rpm by a set percentage. (The overspeed governor setting is adjustable).

Overtemperature: Any exhaust temperature that exceeds the minimum allowable temperature for a given operating condition.

Plenum: A duct, housing or enclosure used to contain air under pressure.

Power: A measure of the rate at which work is performed, i.e., the amount of work accomplished per unit of time.

Power Lever: Cockpit lever used to change propeller pitch during beta operation and to select engine fuel flow during Prop Governing Mode.

Pressure Altitude: The altitude in the atmosphere corresponding to the given air pressure.

Pressure Ratio: In a gas turbine engine, the ratio of compressor discharge pressure to compressor inlet pressure. For example, an inlet pressure of 15 psia (absolute pressure) and a discharge pressure of 150 psia would be expressed as a pressure ratio of 10 to 1.

Primary Air: The portion of the compressor output air that is used for the actual combustion of fuel, usually 20 per cent to 25 per cent.

Primary Fuel: The fuel that is sprayed into the combustion chamber from the primary fuel nozzles. At low airflows it is the only fuel supplied. At high airflows it supplements the main fuel.

Probe: A sensing element that extends into the air stream or gas stream for measuring pressure, velocity, or temperature.

Prop Governing: An engine mode of operation wherein the prop governor selects blade pitch to control engine rpm, and fuel flow is established manually.

Psia: Pressure expressed in pounds per square inch (lb/in^2) compared with the pressure (zero) in a perfect vacuum. The "a" is for absolute.

Psig: The increase in pressure (lb/in^2) inside tube, plenum, or duct compared with the ambient pressure surrounding it. The "g" is for gage.

Purge Cycle: Clearing the combustion chambers to remove unburned fuel by rotating the engine with the starter. The airflow caused by the compressor will carry off dangerous accumulations of gaseous fuel vapors present.

Radial (Compressor, Turbine): A device containing blades that lie along the radius of the wheel or rotor. On a compressor, air flows outward from the center; on a turbine, air flows in toward the center.

Resilient Mount: A spring or O-ring supported bearing mount which helps counteract the effects of imbalance and vibration by absorbing radial loads.

Rotor (Compressor or Turbine): A rotating disc, or drum, to which a series of blades are attached.

Rotor (Seal): The rotating portion of a seal.

Scavenge Pump: A pump used to remove oil from bearing pockets, or voids, after the oil has been used for lubricating and/or cooling.

Scroll: A snail-shell-like housing surrounding a radial turbine, through which pressurized air from the compressor enters.

Secondary Air: The portion of compressor output air that is used for cooling combustion gases and engine parts.

Secondary Fuel: The fuel admitted by the flow divider to the secondary nozzles in the combustion chamber at high airflow. It is sometimes called main fuel.

Shroud: A cover, or housing, used to aid in confining an airflow or gas flow to a desired path.

Slug: A standard unit of mass frequently used in aeronautical computations. It is equal in pounds to the feet per second per second traveled by a freely falling body at a given location. Where the acceleration of gravity is 32.17 feet per second per second, one slug will weigh 32.17 pounds. With changes in gravitational force the mass remains constant at one slug but its weight changes.

Specific Gravity: The ratio of the mass of a liquid to the mass of an equal volume of water at some standard temperature.

Specific Weight: The ratio of the weight of a homogenous fluid to its volume, at a given temperature and pressure; also called weight density.

Stage (Compressor): Each stage consists of a row of compressor rotor blades and the following row of stator vanes which together increase the air pressure. Also, a combination of an impeller and its diffuser constitutes a stage.

Stage (Turbine): Each stage consists of a row of turbine nozzle guide vanes and the following row of turbine blades, which together extract power from the hot gases to drive the compressors and accessories.

Standard Day: See Air (Standard)

Start Lock: Mechanical latching device on each prop blade used to maintain the propeller at minimum pitch position during engine starting.

Static Balance: The equilibrium of a rotating body that has its center of mass on its rotational axis. A standing balance.

Static Pressure: The pressure energy of a fluid due to the random motion and concentration of the molecules.

Static Thrust: The force which the engine exerts against its mounts while it is operating but not moving.

Stator: A row of stationary guide vanes which direct the airflow between the rows of rotor blades.

Sustaining Speed: The speed of the compressor and turbine at which the engine can keep running without depending upon power from the starter.

Tailpipe Temperature: (See Exhaust Gas Temperature)

Thermal Efficiency:

$$\frac{\text{Work supplied to load}}{\text{Heat energy supplied (fuel)}} = \text{Thermal Efficiency}$$

Thrust: A pushing force exerted by one mass against another, which tends to produce motion. In jet propulsion, thrust is the force in the direction of motion caused by the pressure if reactive forces on the inner surfaces of the engine. Thrust force is generally measured in pounds.

Torque: The effectiveness of a force in setting a body into rotation. Measured in ft. lb.

Torus: Doughnut-shaped air duct which collects the gases from the combustor(s) and directs them to the turbine nozzle.

Turbine: A rotating device turned either by direct or reactive forces (or a combination of both), and used to transform some of the kinetic energy of the exhaust gases into shaft horsepower to drive the compressor(s) and accessories.

Turbine Blade: Fin mounted on the turbine disc, shaped and positioned to extract energy from the exhaust gases to rotate the disc.

Turbine Mechanical Efficiency: A measure of the efficiency of the turbine in converting fluid energy into useable mechanical energy.

Turbine Exhaust Cone: A fixed or adjustable bullet-shaped structure over which the exhaust gases pass before converging in the exhaust section.

Turbine Inlet Temperature (TIT): Temperature of hot gases as they enter the engine turbine. Also referred to as T4.

Turbojet: A gas turbine whose entire propulsive output is delivered by the jet of gases through the turbine nozzle.

Turboprop: A type of gas turbine that converts heat energy into propeller shaft work and some jet thrust.

Underspeed Governor (USG): Flyweight operated fuel metering device, housed in the fuel control; it establishes engine rpm during Beta Mode of operation.

Vanes, Stator: Stationary airfoils that direct air or gases from stage to stage in the compressors or turbines.

Velocity: The rate of change of distance with respect to time. The average velocity is equal to total distance divided by total time.

Viscosity: Measurement of a fluid's resistance to flow under an applied force.

Volume Flow: Flow of fluid measured in units of volume per unit of time such as cubic feet per second.

Weight Flow: Flow of fluid measured in units of weight per unit of time such as pounds per hour.

ABBREVIATIONS FOR TERMS

a	-	Used as a subscript, denotes "air"
b	-	Used as a subscript, denotes "bleed"
A_B	-	Bleed area
abs	-	Absolute
AC	-	Alternating current
amb	-	As a subscript, denotes "ambient"
APU	-	Auxiliary power unit
ATS	-	Air Turbine Starter
Btu	-	British thermal unit
°C	-	Degrees Centrigrade or Celsius
c	-	As a subscript, denotes "compressor"
CDP	-	Compressor discharge pressure. Also termed PCD
cfm	-	Cubic feet per minute
ccw	-	Counterclockwise
cw		Clockwise
DC	-	Direct current
EECM	-	Engine electronic control module
EFR	-	Engine flat rate
EGT	-	Exhaust gas temperature
ESHP	-	Equivalent shaft horsepower
f	-	Used as a subscript, denotes "fuel"
°F	-	Degrees Fahrenheit

F.O.D. - Foreign object damage

g - Used as a subscript, denotes "gas"; used alone denotes acceleration due to gravity. 32.17 ft/sec^2, or a unit of acceleration equal to gravity.

gpm - Gallons per minute

H_g - Mercury

HOT - High oil temperature

Hz - Hertz (Frequency in cycles per second)

LOP - Low oil pressure

Mn - Maximum speed

NDC - Nameplate data and configuration control

N_1 or N_L - Low pressure rotor speed

N_2 - High pressure rotor speed

OAT - Outside air temperature

PLA - Power level angle

pph - pounds per hour

PSHP - Propeller shaft horsepower

psi - Pounds per square inch

psia - Pounds per square inch absolute

psig - Pounds per square inch gage (pressure greater than ambient)

P - Pressure
- P_D - Discharge pressure
- P_o - Interstage pressure
- P_{CD} - Compressor discharge pressure
- P_r - Servo pressure
- P_L - Metering valve underside pressure

rpm
or
RPM - Revolutions per minute

s - Used as a subscript, denotes a static (unmoving) condition.

SHP - Shaft horsepower

SL - Sea level

SOAP - Spectrometric Oil Analysis Program

T - Temperature

t - Used as a subscript, denotes "turbine" or "total"; used alone, it denotes "time".

TAS - True airspeed

THP - Thrust horsepower

SYMBOLS

α (Alpha) - Angle of attack; angular difference between the direction of airflow and the angular position of the surface which it will contact.

β (Beta) - Pitch angle of a propeller

Δ (Delta) - Difference between two values; change in value.

δ (Delta) - Ratio of the pressure of air entering a device to so-called "standard" pressure at sea level; P/29.92.

σ (Sigma) - Correction factor for air flow; 17.35 x P/T where P is pressure in inches of mercury absolute, and T is temperature in degrees Fahrenheit plus 460.

θ (Theta) - Ratio of absolute temperature of air (°F plus 460) entering a device to "standard" temperature; T abs/519.

ϕ (Phi) - Phase, or phase angle.

CENTIGRADE - FAHRENHEIT CONVERSION TABLE

$F = 9/5\,C + 32 = 1.8\,(C + 17.8)$
$C = 5/9\,(F - 32)$

C	← F ↓ C →	F
-62.2	-80	-112
-56.7	-70	-94
-51.1	-60	-76
-45.6	-50	-58
-40.0	-40	-40
-34.4	-30	-22
-31.7	-25	-13
-28.9	-20	-4
-26.1	-15	5
-23.3	-10	14
-20.6	-5	23
-17.8	0	32
-15.0	5	41
-12.2	10	50
-9.4	15	59
-6.7	20	68
-3.9	25	77
-1.1	30	86
1.1	35	95
4.4	40	104
7.2	45	113
10.0	50	122
12.8	55	131
15.6	60	140
18.3	65	149
21.1	70	158
23.9	75	167
26.7	80	176
29.4	85	185
32.2	90	194
35.0	95	203
37.8	100	212
40.6	105	221
43.3	110	230
46.1	115	239
48.9	120	248
51.7	125	257
54.4	130	266
57.2	135	275
60.0	140	284
62.8	145	293
65.5	150	302
68.3	155	311
71.1	160	320
73.9	165	329
76.7	170	338
79.4	175	347
82.2	180	356
85.0	185	365
87.8	190	374
90.6	195	383
93.3	200	392
96.1	205	401
98.9	210	410
101.7	215	419
104.4	220	428
107.2	225	437
110.0	230	446
112.8	235	455
115.6	240	464
118.3	245	473
121.1	250	482

C	← F ↓ C →	F
126.7	260	500
132.2	270	518
137.8	280	536
143.3	290	554
148.9	300	572
154.4	310	590
160.0	320	608
165.6	330	626
171.1	340	644
176.7	350	662
182.2	360	680
187.8	370	698
193.3	380	716
198.9	390	734
204.4	400	752
210.0	410	770
215.6	420	788
221.1	430	806
226.7	440	824
232.2	450	842
237.8	460	860
243.3	470	878
248.9	480	896
254.4	490	914
260.0	500	932
265.6	510	950
271.1	520	968
276.7	530	986
282.2	540	1004
287.8	550	1022
293.3	560	1040
298.9	570	1058
304.4	580	1076
310.0	590	1094
315.6	600	1112
326.7	620	1148
337.8	640	1184
348.9	660	1220
360	680	1256
371.1	700	1292
382.2	720	1328
393.3	740	1364
404.4	760	1400
415.6	780	1436
426.7	800	1472
437.8	820	1508
454.4	850	1562
482.2	900	1652
510.0	950	1742
537.7	1000	1832
565.5	1050	1922
592.2	1100	2012
621.1	1150	2102
648.8	1200	2192
676.6	1250	2282

C	← F ↓ C →	F
704.4	1300	2372
732.2	1350	2462
760.0	1400	2552
787.7	1450	2642
815.5	1500	2732
843.3	1550	2822
871.1	1600	2912
898.8	1650	3002
926.6	1700	3092
954.4	1750	3182
982.2	1800	3272
1010.0	1850	3362
1037.7	1900	3452
1065.5	1950	3542
1093.3	2000	3632
1121.1	2050	3722
1148.8	2100	3812
1176.6	2150	3902
1204.4	2200	3992
1232.2	2250	4082
1260.0	2300	4172
1287.7	2350	4262
1315.5	2400	4352
1343.3	2450	4442
1371.1	2500	4532
1398.8	2550	4622
1426.6	2600	4712
1454.4	2650	4802
1482.2	2700	4892
1510.0	2750	4982
1537.7	2800	5072
1565.5	2850	5162
1593.3	2900	5252
1621.1	2950	5342
1648.8	3000	5432
1676.6	3050	5522
1704.4	3100	5612
1732.2	3150	5702
1760.0	3200	5792
1787.7	3250	5882
1815.5	3300	5972
1843.3	3350	6062
1871.1	3400	6152
1898.8	3450	6242
1926.6	3500	6332
1954.4	3550	6422
1982.2	3600	6512
2010.0	3650	6602
2037.7	3700	6692
2065.5	3750	6782
2093.3	3800	6872
2121.1	3850	6962
2148.8	3900	7052
2176.6	3950	7142
2204.4	4000	7232